THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

ANNUAL REPORT OF THE COUNCIL, 1931-32.

THE Accounts for the year ended December 31st, 1931, together with the Annual Report of the Council for the Session, 1931–32, are hereby submitted.

The following table shows the changes in membership during the year 1931 and the total membership at December 31st, from which it will be seen that the membership continues to increase.

	TOTAL 31.12.30.	CHANGES DURING 1931.							TOTAL 31.12.31.
		New.	Transferred to.	Resigned.	Deceased.	Removed.	Transferred from.	+ —	
Honorary Members ..	14	—	—	1	—	—	—	— 1	13
Members	547	38	7	8	8	8	—	+21	568
Associate Members ..	458	36	15	11	3	13	7	+17	475
Students	131	18	—	3	1	3	14	— 2	129
Associates	87	12	—	2	1	1	1	+ 7	94
TOTALS	1237	104	22	24	13	25	22	+42	1279

In addition to the above, on December 31st, 1931, 8 members, 7 associate members and 4 students had been elected but had not taken up their membership, and 24 candidates were waiting election.

The Council regret to have to announce the death of the following members: The Rt. Hon. Lord Forres, Duncan Garrow, T. T. Gray, A. W. Ibbett, W. G. Lindsay, Hubert May, H. F. Moon, Arthur Moore, E. W. H. Peel, D. K. Peters, Robert Redwood, P. B. Roberts, W. G. Watkins.

The Accounts for the year ending, and Balance Sheet as at, December 31st, 1931, are presented.

The policy of issuing the Journal in 12 monthly parts throughout the year has enabled the Council to effect a number of economies, which are reflected in the improved financial position shown.

The Scholarships awarded by the Institution have been provided for in the Accounts, and it has been decided to continue the awards for the year 1932.

The Committee for the Standardisation of Methods of Testing Petroleum and its Products has continued to hold its meetings. Several new sub-committees have been formed to deal with special subjects, such as the Knock-Rating of Motor Fuels and the Measurement of Oil in Bulk.

The Institution is represented on the following: British Standards Institution, the American Society for Testing Materials, the Advisory Board of the Department of Oil Engineering and Refining of the University of Birmingham, the British Association for the Advancement of Science, the Fuel Economy Committee, the Imperial Mineral Resources Bureau, the British Committee of the World Power Conference, the Mechanical Warfare Board of the War Office, and Ramsay Memorial Laboratory Advisory Committee.

Official delegates attended, on behalf of the Institution, the following: the Centenary Celebrations in Honour of Michael Faraday; the 11th Congress of Industrial Chemistry at Paris on September 27th to October 4th, 1931; the Lubrication Oil Congress at Strasburg, July 20th–26th, 1931; and the 3rd International Conference on Bituminous Coal at Pittsburg.

Joint meetings have been held with the Institution of Automobile Engineers, on March 31st, and the Institute of Fuel, on October 7th, 1931.

Eight general meetings of the Institution were held during the year 1931, at which the following papers were read and discussed:—

One Hundred and Thirty-second and One Hundred and Thirty-third General Meetings, January 13th and February 10th, 1931, respectively: "Symposium on Salt Domes."

One Hundred and Thirty-fourth General Meeting, March 10th, 1931: "Fuel Testing in Slow and High Speed Diesel Engines," by L. J. Le Mesurier and R. Stansfield.

Eighteenth Annual General Meeting, March 31st, 1931: "Induction of Incoming President."

One Hundred and Thirty-fifth General Meeting, April 14th, 1931: "Recent Developments in Fractional Distillation," by C. H. S. Edmonds.

One Hundred and Thirty-sixth General Meeting, May 12th, 1931: "Knock Rating of Motor Fuels," by C. H. Barton, C. H. Sprake and R. Stansfield.

One Hundred and Thirty-seventh General Meeting, October 13th, 1931: "Sweating of Paraffin Wax," by H. L. Allen.

One Hundred and Thirty-eighth General Meeting, November 10th, 1931: "The Dilution Theory of Detonation," by I. A. J. Duff.

One Hundred and Thirty-ninth General Meeting, December 8th, 1931: "Geology of Zante," by Dr. A. Wade.

The meetings continue to be held at the House of the Royal Society of Arts, John Street, Adelphi, London, W.C. 2, and the Council beg to tender their thanks to that Society for their courtesy.

Volume XVII. of the Journal was published in twelve monthly parts and, in addition to the papers read at the meetings, contain a number of contributed articles and also abstracts of current technical literature and patent specifications.

The Students' Section at London and Birmingham report the regular holding of meetings and reading of papers. The interest in these sections is maintained and they continue to show satisfactory advance.

Seven papers were submitted for Students' Medal and Prize for the 1930–31 session. The Medal and Prize were awarded to Mr. N. G. Gullick, of the Royal School of Mines, for his paper on "The Determination of Mean Molecular Weights of Lubricating Oils by Improved Cryoscopic Methods." Mr. C. F. C. Moore was commended for his paper on "Shale Mines of Scotland," and Mr. T. Gordon Robson for his paper on "Oil Field Waters."

The Institution's scholarships for 1930–31 were awarded to Mr. D. G. Hobson, of the Royal School of Mines, London, and Mr. M. E. Kelly, at Birmingham University.

Mr. James Kewley, M.A., F.I.C., F.C.S., M.I.Chem.E., has been unanimously re-elected President for the ensuing year, and Sir John Cargill, Mr. A. E. Chambers, Mr. T. Dewhurst, Mr. Alexander Duckham, Mr. Arthur W. Eastlake and Mr. A. Beeby Thompson have been unanimously re-elected as Vice-Presidents.

The Council is pleased to note that the Branches in Persia, Roumania, South Wales and Trinidad continue in active progress and render definite assistance to the Parent Institution in many ways.

The Council regret that Miss Despard, owing to continued ill-health, found it necessary to resign the post of Librarian. Arrangements have been made for carrying on the work of the Library in conjunction with the work of editing the Journal, Mr. G. Sell having taken over the supervision of the Library. A new Library Committee has been established, apart from the Publication Committee, and is taking an active interest in the development of the Library.

The Council again desire to call attention to the Benevolent Fund, and it is hoped that members will subscribe generously and regularly to the Fund. By the will of the late Mr. Robert Redwood the sum of £200 was bequeathed to this Fund. For the convenience of those members who desire to make an annual subscription a banker's order may be obtained from the Secretary of the Institution.

The Thirteenth Annual Dinner was held at the Connaught Rooms, Great Queen Street, London, on October 9th, 1931, and was attended by over 200 members and guests.

The Council beg to tender their thanks to the following for their services rendered to the Institution: Lord Plender, G.B.E., Honorary Treasurer; Messrs. Ashurst, Morris, Crisp and Co., Honorary Solicitors; Messrs. Price, Waterhouse and Co., Auditors; and the Editorial, Library and Office Staffs.

The Auditors retire and, being eligible, offer themselves for re-election.

By Order of the Council,

ARTHUR W. EASTLAKE,

Honorary Secretary.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

BENEVOLENT FUND.

FOR THE YEAR ENDED 31ST DECEMBER, 1931.

	£ s. d.	£ s. d.		£ s. d.
Balance at Bank on Current and Deposit Account, 1st January, 1931		189 2 11	Grants in Aid	32 3 0
Donations..	213 10 6		Balance at Bank on Current and Deposit Account, 31st December, 1931	414 2 8
Subscriptions	28 9 6			
		242 0 0		
Contribution by Trinidad Branch		12 10 0		
Interest on Deposit Account ..		2 12 9		
		£446 5 8		£446 5 8

Members of the Committee :—
ALFRED C. ADAMS.
J. KEWLEY.

We have examined the above Account with the books and vouchers of the Fund and find the same to be correct.

3, Frederick's Place,
Old Jewry,
London, E.C. 2.
25th January, 1932.

PRICE, WATERHOUSE & CO.

Dr. REVENUE ACCOUNT FOR THE

	£	s.	d.
To Salaries	1028	12	4
„ Rent, Rates, etc.	445	0	9
„ Printing and Stationery	170	4	4
„ Postage	246	4	2
„ Expenses of Meetings, Including Hire of Hall	209	9	3
„ Journals and Publications (Net Expense)	505	11	0
„ Grants to Branches	91	0	0
„ Sundry Expenses	391	4	5
„ Auditors' Fee	10	10	0
„ Students' Prize and Scholarship Fund	80	0	0
„ Depreciation of Office and Library Furniture and Library Books	62	2	8
„ Students' Section	18	3	2
„ Balance, being Surplus for the Year Carried to Balance Sheet	1	2	1
	£3259	4	2

STUDENTS' PRIZE AND

1931.		£	s.	d.	£	s.	d.
Dec. 31.	To Scholarships Granted—						
	Imperial College of Science and Technology ..	40	0	0			
	Birmingham University	40	0	0			
					80	0	0
	„ Balance Carried Forward				5	0	0
					£85	0	0

RESEARCH

1931.		£	s.	d.
Dec. 31.	To Fellowship Grant	198	0	0
	„ Grant for Research	20	0	0
	„ Balance Carried Forward	541	5	9
		£759	5	9

YEAR ENDED 31ST DECEMBER, 1931. Cr.

	£ s. d.	£ s. d.
By SUBSCRIPTIONS—		
Members	3081 9 6	
Special	20 0 0	
		3101 9 6
„ INTEREST AND DIVIDENDS LESS TAX		157 14 8
		£3259 4 2

SCHOLARSHIP FUND.

1931.		£ s. d.
Jan. 1.	By BALANCE BROUGHT FORWARD	5 0 0
Dec. 31.	„ REVENUE ACCOUNT	80 0 0
		£85 0 0

FUND.

1931.		£ s. d.
Jan. 1.	By BALANCE BROUGHT FORWARD	739 7 3
Dec. 31.	„ INTEREST AND DIVIDENDS LESS TAX	19 18 6
		£759 5 9

BALANCE SHEET AS

	£ s. d.	£ s. d.	£ s. d.
CAPITAL OF THE INSTITUTION, under Bye-Law Section 6, paragraphs 14 and 15 :—			
Life Membership Fund—			
As at 31st December, 1930		519 0 0	
Entrance Fees—			
As at 31st December, 1930	1957 3 0		
Additions during year	149 2 0		
		2106 5 0	
Profit on Sale of Investments—			
As at 31st December, 1928		2 10 0	
Donations—			
As at 31st December, 1928		326 5 0	
			2954 0 0
STUDENTS' PRIZE AND SCHOLARSHIP FUND..			5 0 0
RESEARCH FUND			541 5 9
MEMBERS' SUBSCRIPTIONS PAID IN ADVANCE			166 6 9
JOURNAL SUBSCRIPTIONS PAID IN ADVANCE			358 18 4
SUNDRY CREDITORS			247 14 9
REVENUE ACCOUNT :—			
Balance as at 31st December, 1930 ..		1315 7 1	
Less : Subscriptions, 1929-30, now written off		116 0 6	
		1199 6 7	
Add : Surplus for year as per separate account		1 2 1	
			1200 8 8
			£5473 14 3

Members of Council { J. KEWLEY. ALFRED C. ADAMS.

AUDITORS'

To the Members of

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.

We have examined the above Balance Sheet with the books of the Institution are of opinion that such Balance Sheet is properly drawn up so as to exhibit a true according to the best of our information and the explanations given to us and as

3, FREDERICK'S PLACE,
OLD JEWRY, LONDON, E.C. 2.
5th February, 1932.

AT 31ST DECEMBER, 1931.

	£ s. d.	£ s. d.
INVESTMENTS AT COST :—		
On Account of Capital—		
£1250 0 0 5% War Loan 1929/47	1196 18 6	
650 0 0 3½% Conversion Loan	505 7 0	
664 6 6 London County 3% Consolidated Stock	481 10 6	
150 0 0 Birmingham Corporation 6% Stock 1936/46	146 16 0	
100 0 0 Wigan Corporation 5% Redeemable Stock	99 14 11	
160 0 0 New South Wales 5% Stock 1945/65..	158 7 0	
100 0 0 5% Conversion Stock 1944/64 ..	102 3 6	
150 0 0 London and North Eastern Railway 4% Sinking Fund Debenture Stock ..	138 13 6	
		2829 10 11
(Market value at 31st December, 1931, £2672 17s. 5d.)		
On Account of Revenue—		
£800 0 0 5% War Loan 1929/47		810 15 9
(Market value at 31st December, 1931, £768)		
On Account of Research Fund—		
£500 0 0 5% War Loan 1929/47		510 8 3
(Market value at 31st December, 1931, £480)		
OFFICE AND LIBRARY FURNITURE (excluding Presentations) :—		
As at 31st December, 1930	442 13 0	
Additions during year	4 0 0	
	446 13 0	
Less : Depreciation	22 2 8	
		424 10 4
LIBRARY BOOKS (excluding Presentations) :—		
As at 31st December, 1930	160 0 4	
Additions, less sales, during year	11 11 3	
	171 11 7	
Less : Depreciation	40 0 0	
		131 11 7
MEMBERS' SUBSCRIPTIONS OUTSTANDING CONSIDERED COLLECTIBLE		82 14 0
SUNDRY DEBTORS AND PAYMENTS IN ADVANCE ..		59 14 2
CASH ON DEPOSIT WITH BANKS :—		
Research Fund	36 2 6	
General Account	300 0 0	
		336 2 6
CASH AT BANK AND IN HAND		288 6 9
		£5473 14 3

REPORT.

and have obtained all the information and explanations we have required. We and correct view of the state of the Institution's affairs at 31st December, 1931, shown by the books of the Institution.

PRICE, WATERHOUSE & CO.

INSTITUTION OF PETROLEUM TECHNOLOGISTS.

THE NINETEENTH ANNUAL GENERAL MEETING of the Institution of Petroleum Technologists was held at the Royal Society of Arts, John Street, Adelphi, W.C., on Tuesday, March 8th, 1932, Mr. James Kewley, M.A., F.I.C., F.C.S., President, occupying the Chair.

The Secretary read the notice convening the meeting and the auditors' certificate.

Minutes of Previous Annual Meeting.

The Secretary read the minutes of the Eighteenth Annual General Meeting, which were confirmed and signed.

Result of Ballot for Council.

The Secretary announced that six nominations for election to the Council to fill four vacancies had been received. The ballot had resulted in the re-election of Mr. A. Frank Dabell, Professor A. W. Nash and Mr. T. R. H. Garrett, and the election of Lieut.-Col. S. J. M. Auld.

New Members.

The list of new members nominated and elected was taken as read. The list showed that there were 38 new Members, 7 Associate-Members transferred to Members, 36 new Associate-Members, 15 Students and Associates transferred to Associate-Members, 18 Students and 12 Associates.

The Secretary read the following list of members elected since the last meeting, and also the list of nominations.

As Members.—Iain Cameron, Wolfgang Grote, Wilfred Thomas Jarrett, Arnold Kirk Steel, Robert E. Wilson.

As Transference to Member.—Leonard Arthur Toone.

As Associate Members.—Robert Bleakley, Robert Jones Evans, John Edgar Halliday.

As Associate.—Brian Morris Patrick O'Hea.

Annual Report of Council, 1931-32.

The President, in moving the adoption of the Annual Report of Council for the Session 1931-32, said he desired to say a few words only in amplification of the report, which was in the hands of members. He proposed to deal with the report generally, leaving Mr. A. C. Adams, the Chairman of the Finance Committee, to deal with the financial section separately.

The increase of membership was, on the whole, quite satisfactory. Forty-two represented the normal rate of increase during the last few years. The Institution had now members in no less than 50 different countries, as against 30 countries ten years ago. Since 1921 the membership in the United Kingdom had doubled, in Japan it had increased five-fold, and in Roumania eleven-fold. In only five of the smaller countries had the membership shown any decrease. He desired to draw attention to the fact that the only diminution in membership was in the Students' Section, which he regarded as rather unfortunate, because the students were potential future members. He thought it was the duty of all members to do everything they could to encourage young men to become Student Members of the Institution.

Among those whom the Institution had lost by death he desired to mention particularly Robert Redwood, one of the founders of the Institution and a vice-president. For many years Mr. Redwood had taken a very active interest in the affairs of the Institution. Members of the Council who had been brought into contact with him would particularly miss him as a wise counsellor and a friend of peculiar personal charm.

The issue of the Journal in twelve monthly parts had definitely proved a success. It had added to the reputation of the Institution, and had not been a source of extra expense. The hundredth number of the Journal was published in February last. In connection with a special meeting at which Dr. Dunstan had very kindly entertained the members of the Publication Committee, Mr. Sell had presented a few notes which were of interest. The first number of the Journal was published in August, 1914, and contained 36 pages. No. 100 was made up of 74 pages of transactions and 38 pages of abstracts, a total of 112 pages. Vol. I. of the Journal, 1914–1915, was published in four parts, and Vol. XVII. in twelve. The number of pages in the first volume of the Journal was 328, and in the last volume 1330; so that if the progress of the Journal represented the progress of the Institution as a whole, they had cause to congratulate themselves, and especially Dr. A. E. Dunstan, Mr. George Sell, Mr. W. H. Thomas and the members of the Publication Committee, on their signal success.

Of the Standardization Committee he would have something to say later in his presidential address.

It would be seen that the Institution had been represented on a number of bodies. The growing interest in the Institution on the part of outside bodies was very gratifying. To that list there might now be added the National Physical Laboratory, which recently invited the Institution to send a representative to its newly formed conference of engineers. The movement in the

direction of joint meetings between various societies was a step in the right direction, and was indicative of the spirit of co-operation which was springing up.

In connection with the Students' Section he asked senior members to devote, if possible, a little of their time and interest to the work of the students. At the request of the students themselves, last year three of the senior members, Mr. C. Dally, Mr. W. W. Goulston and Mr. R. J. Ward had kindly read papers to students. The thanks of the Institution were especially due to Mr. Ashley Carter, who had shouldered the responsibility of looking after the students, and who had made that his hobby.

In connection with the reorganisation of the Library, which was referred to in the report, he wished particularly to thank Mr. John Gillespie, Member of Council, who was taking a very keen personal interest in the work, and was giving up a considerable amount of time to the actual library work. In that he was following the excellent example set by other members of Council in applying themselves to one particular job and making that their hobby.

As regards the Benevolent Fund, he found it a little difficult to make a further appeal at the present time. Fortunately the demands on the Fund had not been very great so far, and the Institution had been fortunate in having had two legacies; but, nevertheless, every member of the Institution ought to feel it his duty to make some small contribution to the Fund. There were 1279 members at present, and if every one made a point of giving even a shilling or two it would very considerably increase the funds available.

As regards the Research Fund, there was at present available a balance of about £530 for research. The Council would be very glad to have any definite, constructive suggestions as to the ways in which that money could be spent. Although the fund had been in existence for some time, the Council felt that it was not quite sufficiently generally known. The Council did not receive any number of applications for smaller or larger grants.

He thanked all members of the Council for the great assistance they had rendered to him, and for making the duty of presiding over the Institution a particularly pleasant one.

The President then formally moved the adoption of the Annual Report, and called upon Professor Brame to second.

Prof. J. S. S. Brame, in seconding, said that after the very satisfactory account which the President had given there was nothing more that he could say in connection with the report.

The Annual Report was adopted.

Balance Sheet and Accounts for 1931.

The President formally moved the adoption of the Accounts and Balance Sheet for the year 1931, and asked Mr. Adams to be good enough to give what little explanation was necessary on the financial section of the report. He coupled with this request a vote of thanks to Mr. Adams for the very great personal interest he had taken in the financial affairs of the Institution.

Mr. A. C. Adams (Chairman of Finance Committee), pointed out that the accounts showed a surplus on the year's working. That was as it should be, of course, although the amount of credit was not a large one. The surplus shown for the year was £1 2s. 1d., but this figure might have been somewhat larger, except that it was thought prudent to deal with the question of depreciation rather more liberally than had previously been the practice. Moreover, in view of the large amount of members' subscriptions outstanding at what everyone recognised as a very difficult time, it was considered advisable to deal with the item of members' subscriptions on rather more conservative lines than usual. An added depreciation had been taken on library books. The sum now shown in the balance sheet amounted to an equivalent of 25 per cent., and in the case of members' subscriptions, those outstanding prior to 1931 had been excluded altogether. It was true that some of them might come in later; experience showed that they generally did; but the Finance Committee were not reckoning upon getting them all in, so they had excluded those which were outstanding prior to 1931, and they had taken into credit only half of the 1931 subscriptions remaining outstanding at the end of the year. That, of course, was a very conservative way of dealing with the revenue, and he thought it certainly showed the financial position in a strictly correct way. Although it was not, perhaps, absolutely necessary to deal with subscriptions in that way, nevertheless they thought, in all the circumstances, that it was prudent to do so.

The net result showed that the surplus for the year was £1 2s. 1d. He hoped that members would consider that the balance sheet in other respects did reflect a satisfactory financial position. Looking at the balance sheet, he did not think there were many items upon which he need comment, because he had spoken about all of them on many other occasions, and to do so again would be merely a matter of repetition. The capital of the Institution had increased during the year through entrance fees by nearly £150, and that amount was in hand for investment at the end of the year. The investments shown on the other side represented the investment of the capital of the Institution at cost, and the valuations shown on the balance sheet were the market valuations as at December 31st.

He did not think that members need feel any anxiety as to that valuation, because if a new valuation were taken at the present time it would show a very much nearer market agreement with the investment cost.

The Students' Prize and Scholarship Fund represented moneys in hand for those purposes. There were members' subscriptions and Journal subscriptions paid in advance, which had to be reserved, as they only ranked in 1932; and the sundry creditors represented the usual outstandings at the accounting period, which had, of course, since been paid.

Looking at the Revenue Account, it would be seen that the various items of expenditure had followed a normal course, except that the expense of publishing journals and publications showed at £505 11s. as against the 1930 figure of £836. The President had already mentioned that in publishing the Journal in twelve monthly parts the Council had been able to take advantage of an opportunity for economy, which had conformed to the expectations formed last year. It would be remembered that he had commented upon this, in his remarks on the previous year's balance sheet, as being an economy which the Council anticipated it would be possible to make.

It was gratifying to know that the Council had been able to carry out its programme without the necessity of drawing upon the unspent funds of the Institution, which were held in reserve. Those moneys were all available at any time when it became necessary for the Council to call upon them to be spent for the benefit of the Institution.

The accounts and balance sheet were adopted.

Annual Reports of Students' Section.

The Secretary read the Annual Reports of the Students' Section for the year 1931, as follows :—

London Branch.—On December 31st, 1931, the Student Members of the Institution numbered 129. During the year under review, there were, in the London Area, 10 New Members, to whom a hearty welcome is extended; 7 Members transferred; 1 removed; and 2 resigned.

At the Eighth Annual General Meeting, held in March, 1931, the following were elected to serve on the Committee: Messrs. J. E. Duckham, G. Richardson, C. L. Lee, J. W. Clack, L. G. M. Roberts, and P. A. Spens. Mr. Duckham was subsequently elected Chairman, and Mr. P. A. Spens, Hon. Secretary.

During 1931, eight meetings were held :—

January.—"The Scottish Shale Oil Industry," by C. S. Lee, Stud.I.P.T.

February.—The Anglo-Persian Film of "The Scottish Shale Oil Industry," by W. B. Rowntree, A.M.I.P.T.

February.—The "Geophysical Film," by J. C. Templeton, B.Sc., F.G.S., A.M.I.P.T.

March.—Eighth Annual General Meeting.

April.—"Lightning Protection and Static Electricity in the Petroleum Industry," by C. Dalley, M.I.E.E.

May.—"The Molecular Structure of Some Lubricating Oils," by N. G. Gullick, Stud.I.P.T.

October.—"Cracking," by W. W. Goulston, M.I.P.T.

November.—"The Opening Up of an Oilfield," by R. J. Ward, M.I.P.T.

The attendance at meetings during the past year has been extremely good, and shows over a 100 per cent. increase on that of 1930. This shows a much better spirit on the part of the Section, and also an appreciation of the work done for it during 1930 by the President, Mr. Ashley Carter, and other Senior and Student Members. At the same time the Committee would like to see a large number of Students who have not as yet attended many meetings.

Three Papers were entered for the Student's Medal and Prize in the London Area, and the Committee would like to congratulate, on behalf of the Section, Mr. N. G. Gullick, of the Royal School of Mines, who won the medal with his paper on "The Molecular Structure of Some Lubricating Oils."

We hope now that the Medal will come to London regularly, and that more people will enter papers.

The Committee would like to remind the Section that a Grant of £10 per year is made to assist Students in the financial side of the preparation of papers. There is also a Student's Lending Library section of the Institution's Library, of nearly 200 books. Very little, if any, use is made of this Library at the present time.

The Council has awarded the Scholarship at the Royal School of Mines to Mr. G. D. Hobson.

In conclusion the Committee wishes to thank all those Senior Members of the Institution who have attended the meetings and aided the Section both with Papers and in the discussions. In particular they would like to thank Mr. Ashley Carter, in his capacity of sponsor, for showing so much interest in and giving such useful help to the Section.

(Signed) GEO. RICHARDSON,
March 1st, 1932.

(Signed) P. A. SPENS,
Honorary Secretary.

(Signed) J. KEWLEY, March 8th, 1932.

Birmingham Branch.—The Committee has pleasure in presenting the Ninth Annual Report, for the year ended December 31st, 1931.

At the Annual General Meeting the following officers for this branch were elected: Mr. D. A. C. Dewdney (Chairman), Mr. E. E. Thorneloe (Vice-Chairman), Mr. L. V. Woodhouse Clark (Hon. Secretary and Treasurer), Messrs. Kelly and Darley. Two other representatives to be elected.

Three papers were entered for the Student's Medal and Prize from the Birmingham Branch, and honourable mention was made of the paper by Mr. T. Gordon Robson on "Oil Field Waters."

During the year five meetings were held and attendances at these were consistently good, the average attendance being nineteen.

The following meetings were held and papers read:—

January 20th.—"Pipelines," by Mr. F. K. Naficy.
"Mud Fluids," by Mr. M. J. Mehler.

March 3rd.—"Recent Developments in Oil Field Production," by Mr. R. B. Rogers.

March 17th.—Annual General Meeting.

May 5th.—"Lubricating Oils," by Mr. A. Parkideh.

November 17th.—"Design of Gasoline Absorption Plants." by Mr. T. G. Hunter.

Owing to the depressed condition of trade no visits to Engineering Works were made during the year.

(Signed) L. V. WOODHOUSE CLARK.

(Signed) J. KEWLEY, March 8th, 1932.

Re-Election of Auditors.

On the motion of Mr. Charles Dabell, seconded by Mr. C. W. Wood, Messrs. Price, Waterhouse & Company were duly re-elected Auditors for the ensuing year.

Other Business.

The President announced that before concluding the business meeting and admitting visitors there was an opportunity for any member who wished to do so to bring any point to the notice of the Council.

Dr. W. R. Ormandy said that the Annual Meeting gave the one occasion upon which the ordinary members had an opportunity to bring praise or blame, and that was generally regarded as the sum total of the purpose of the Annual Meeting. He wished neither to praise nor to blame. If he did either, it would surely be to praise, for the Institution was growing in power and influence year by year. He regarded the Annual Meeting as an opportunity for the body of members to put forward any suggestions for improvements which they might think advisable to bring to the notice of the Council. During the time when he had been actively associated with the proceedings of the Institution he had tried very hard to get closer co-operation between the Institution and the Institution of Automobile Engineers. He was on the Council of both Institutions, and unfortunately when such matters were brought up at the Council meetings on both sides the time was never opportune. But co-operation was in the air, and by the courtesy of the President he had learnt that his Address was to be devoted to the subject of co-operation, and was, therefore, germane to the statement that he wished to make. The necessity for co-operation between this Institution and the Institution of Automobile Engineers was getting more and more pronounced. He had heard that American oil firms were delaying the erection of further cracking plant until they knew what compression ratio was going to be the common compression ratio of this year's motor cars, so that they might put down cracking plant of the right type to give a gasoline which would withstand the pressure which was going to be required by the new cars. The rapidly growing introduction of the Diesel type of engine was bringing it to the mind and knowledge of the engineers in the automobile industry that they required the very closest co-operation with the oil companies as regards the nature of the oil they were to use in their injection engines running at high speed; and he ventured to put forward for the consideration of the Council that it might be a good scheme to have one member of the Council of the Institution of Petroleum Technologists sitting at the meetings

of the Institution of Automobile Engineers, and one of the Automobile Engineers sitting on the Council of the Institution of Petroleum Technologists. It might be that five out of six or seven papers would be of no particular interest to either side, but there would be that close co-operation which was so eminently desirable. He desired to put this forward merely as a suggestion.

The President said he was very glad to have Dr. Ormandy's opportune and constructive suggestion. He had been sorry to hear Dr. Ormandy use the past tense in referring to his active connection with the work of the Institution, and hoped that he would remedy that in the future. As a matter of fact, the Council had to some extent anticipated his suggestion. It was only a few weeks since the Council had considered the possibility of bringing about closer co-operation between the Institution of Automobile Engineers and their own Institution. He personally had had a conversation with Mr. Tookey on the subject, and the Council had gone so far as to form a small sub-committee which would in due course meet to consider the matter. He could assure Dr. Ormandy that this suggestion would be duly brought before the Council.

Dr. Dunstan said that Dr. Ormandy had developed a suggestion which to his mind would inevitably bring forth good results. He would even go a little further, and try to visualise a kind of super-Council of all the various bodies of the type of that Institution, on which a member of the Council of each body would sit to try to bring together a maximum of co-operation.

Mr. Charles Dabell asked what had happened, or what was happening to the Central Housing Scheme. He gathered from the trend of the remarks of the last two speakers that the Institution seem to be drifting again into that scheme.

The President said that the housing scheme was hibernating at present. The option on the building in Victoria Street had necessarily been allowed to lapse. At present practically nothing was being done in regard to the scheme.

Mr. Charles Dabell asked permission to add one more question. He wished to know if there was any method by which members could be apprised of the results of the Council's deliberations without waiting until the Annual General Meeting. He was afraid there was nothing constructive about his question; it was merely a query. Was it possible for members to receive some advice regarding the questions before the Council?

The President asked whether Mr. Dabell felt that members were not kept in touch with the views of the Council.

Mr. Dabell replied that this was so to a certain extent, though he did not want to press the suggestion very far. In the particular instance that had just been mentioned he would consider it advisable to have some method by which members could be apprised.

The President replied that in that particular instance the Council had nothing to tell the members.

Mr. Dabell remarked that it would have been of some value to members even to know that.

The President promised to bring Mr. Dabell's point to the notice of the Council and to consider what could be done to meet it.

Tha President then delivered his Presidential Address.

Co-operation.

By James Kewley, M.A., F.I.C., F.C.S., M.I.Chem.E. (President).

In my remarks at the annual dinner last October I drew attention to the influence which this Institution could exert in the direction of breaking down those barriers to progress, tradition and prejudice, by initiating or taking part in effective co-operative effort in several ways. That the time is ripe for further consideration of this subject is very evident from the attention which it has recently received from several quarters. I propose, therefore, to survey very briefly what has been done in connection with the petroleum industry so far, and to suggest a few directions in which extended co-operation might well be expected to fructify.

We are at present passing through a well-defined phase in the evolution of our civilisation. The characteristic of this phase is rapid change. It has been said that the only constant factor in our modern industrial civilisation is change. We not only experience, but in some cases suffer from, the effects of these changes which develop with kaleidoscopic rapidity. The experience is inevitable and should be beneficial to all, but our lack of understanding of the immediate complex causes and effects of these changes has unfortunately involved much unnecessary suffering. In spite of this lack of understanding and the resulting waves of depression which ensue, a steady, distinct development is making itself felt. There is a definite trend towards closer world social organisation. The art of living together harmoniously in a community, by mutual co-operation, is slowly developing. The general course of the change is, however, determined by a few fundamental factors, in the first place, those which operate in the evolution of any gregarious animal. In the earliest days of man's existence the law

of the survival of the fittest must have had full play, resulting in the development of the efficient physique of the individual. As man, thanks to his unique endowments, rapidly evolved, and as a simple form of community life developed, competition between individuals was supplemented by competition between communities. The civilising effect of the duty towards one's neighbour began to play its part. But as the development of highly organised communities eventually became more rapid, the old spirit of fierce competition evinced itself then between the communities. The nature of the stimulus of competition remained unaltered.

The spirit of self-preservation or competition has played the leading role in the history of mankind, and has been responsible largely, but not entirely, for the vast development of the world's present wealth ; not entirely, because there has developed collaterally as the struggle for existence in the community weakened, a type of man to whom the stimulus of competition in its crude selfish form made little appeal. The stimulus of competition has partly developed into the stimulus of a desire to excel in some peaceful occupation, to do something better than other people, reaching in its highest form that of working for the sake of work, of working for the good of one's fellow man, and for the satisfaction of unravelling more and more of nature's secrets.

That a change of this kind is rapidly taking place is evident on all sides. The general interest in science for its own sake is demonstrated by the remarkable sales of books by men such as Jeans and even Eddington, by the sudden growth of an army of intelligent amateurs in the difficult field of wireless transmission, many of whom as individuals and many more as co-operators have initiated important developments of far-reaching consequence. The actual practical changes need no emphasis ; they follow each other with increasing rapidity. The operation of cause and effect is being speeded up. The new developments have, so to speak, a kind of autocatalytic effect, so that the development as a whole gains rapidly in impetus. This rapid change is a necessary concomitant to the development of a civilisation of ever-increasing complexity. The highest forms of stimulus are gradually replacing the older forms. Indeed, most of the great discoveries of the past which have been the fundamental causes of our development have been the outcome of men of genius to whom the stimulus of selfish competition made little or no appeal. Individual effort, however, must not and cannot be suppressed. The operation of the laws of heredity, which are now being worked out, will see to that. Competition will still be the spice of life, but it will be competition of the healthy type wedded to co-operative effort. The field is becoming too large for individual exploration. Modern expeditions

into nature's unknown require much equipment and organisation and are usually beyond the means of the average worker. Co-operation becomes a necessity.

It appears. also, that the principles of economics based on unrestricted competition, so long regarded as fundamental, will surely be replaced by new principles based on constructive co-operative effort. Mr. H. A. F. Lindsay, in his recent paper on Modern Trade Tendencies, read before the Society of Chemical Industry, has developed this idea.

Now the petroleum industry has been a powerful factor in speeding up the onset of this change. Our industry has developed with a rapidity which at first sight seems extraordinary, but which on consideration appears to be just what one gifted with the scientific imagination of a Jules Verne would have intelligently anticipated.

The great developments which must have followed on the great inventions of the wheel and the application of power provided by domestic animals or water, must have been small in comparison with those ushered in by the development of the engines which laid open the vast possibilities of the utilisation of the energy liberated by the combustion of fuels. Not much more than thrity years ago the petroleum industry, which up to that time had been occupied mainly in the production of illuminating oil, suddenly assumed an importance which has now become immense, in that it facilitated the development of rapid transport, restoring to the roads their former value and opening up an entirely new method which could only have resulted from the collateral development of the internal combustion and suitable liquid fuels. It has directly affected the food supply, in that the development of agricultural machinery has set free the land once occupied for the production of fodder for the animals used for traction purposes. It is estimated that in the U.S.A. alone 26,000,000 acres have so been set free.

The petroleum industry has thus a great responsibility and a great future. Only by realising and shouldering this responsibility can its successful future be assured.

Up to the present, and for some time to come, as far as can be seen, petroleum will supply the best liquid fuels judged from the standpoints of maximum thermal value, cheapness and convenience. In the distant future other fuels, such as alcohol and similar bodies, must take its place, unless the efforts to produce artificial petroleum from coal or other source prove economically successful.

When Sir William Crookes made his famous announcement in 1889 envisaging the impending shortage of nitrogenous fertilisers he could scarcely have dreamed that the method he suggested would in so short a time develop to such an extent that fertilisers

would become a drug in the market. We, too, can envisage a shortage in natural petroleum, perhaps at a distant date, but nevertheless certainly. We can also envisage the production of artificial petroleum, even of cheap petroleum, but this is no excuse for ignoring the fact that the supplies of natural oil are definitely limited, and that we are consuming them at a rate far faster than that at which Nature can possibly replenish the stocks. Nevertheless, the history, and particularly the recent history, of crude oil production affords examples of the results of reckless, selfish and stupid exploitation; fortunately, also of the beneficent results of carefully-regulated co-operative effort in the same field. The scandalous waste of petroleum, primarily in the form of gas, and secondarily in the loss of liquid, the extraction of which is rendered more difficult by the premature release of the gas from the strata, should never be permitted to continue.

I am not in favour, in principle, of the restriction of production, meaning by production the manufacture of articles or products from raw material which exists in great abundance, or the cultivation of replaceable vegetation. Over-production of such articles and materials in a normal world is a fancy. The world is full of people who want goods, who will consume them, and who will work for them. There is no saturation point in consumption. But the restriction of production of a valuable raw material replaceable only at great expense to the extent of preventing its waste is another matter altogether. Much has been written about the effects of the present hysterical production of crude oil from wells giving high initial outputs at costs of production far below that of steady production from the much greater number of the normal small producing wells which are the backbone of the industry and which should determine the costs at which oil can be produced. The danger and stupidity of such production methods which, if continued, will undoubtedly affect the world's resources of natural oil, has been realised and efforts towards co-operative action to remedy this evil have been initiated.

I need only refer to the effort made by the Association of the Roumanian Petroleum Industrialists towards an international conference to discuss production, taking as a basis the scheme put forward by Mr. J. B. A. Kessler. However, co-operation on this basis in the U.S.A. appears to be illegal, as their anti-trust laws do not permit of any agreement involving restriction of production. Until the owner of the surface is only entitled to his rateable share in a common oil or gas pool this irrational method of production will always be possible. The importance of getting this principle legalised is obvious when it is realised that 97 per cent.

of the U.S.A. production comes from privately owned land. The Oil States Advisory Committee have this question in hand, having laid before the Federal Oil Association Board a programme whereby each State would enact uniform conservation laws. But things move slowly. It is certainly discouraging to see that in a country which has in many other directions given a lead in co-operation, the recent disastrous conditions in the oil-producing industry, which afforded an excellent opportunity of effective co-operation, merely proved that such could be effected only by illegal methods.

In the United Kingdom we find many examples of successful co-operation in the manufacture and distribution of goods. There is scope for much more, and this is gradually gaining recognition. Mr. Lindsay, in the paper to which I have previously referred, suggests that science has outrun economics and that science had been quicker to respond to the new spirit, but I venture to suggest that this response is more apparent than real. Science naturally affords many more examples of the operation of the altruistic stimulus than does industry, and if due allowance is made for these, then I think it is obvious that among scientific men and communities there is not yet to be found the co-operation which should be expected. The scientific community has lost many opportunities of taking a more active part in the framing of national and imperial policy. Government committees for the examination of economic development in parts of the Empire have been appointed without adequate representation of scientific bodies, and even without joint protest from such bodies. This is doubtless to be attributed to the fact that many scientific workers do not take sufficient interest in or are indifferent to the possible economic and social results of their work. There is danger in this indifference, and also in the delay of the nation to appreciate the scientific outlook. There is, moreover, some danger that the broad scientific outlook may be obscured or obliterated by the tendency towards specialisation, which is an unavoidable result of the pursuit under present conditions of new knowledge. In this respect, indeed, the scientific men of half a century ago were better off than we are now.

The petroleum industry is still so young that those engaged therein can still take a general survey and be reasonably well acquainted with most modern technical developments. An institution which brings together geologists, engineers, chemists and physicists can still flourish and do real good by enabling effective interchange of views. We can pull much weight by joining whole-heartedly in the co-operative work which has so far been set on foot and by initiating further efforts.

The value of co-operation in research, that insurance against industrial stagnation, is generally recognised. The numerous standing committees of the American Petroleum Institute, with their comprehensive programmes, afford a good example. The co-operation of the American Society for Testing Materials and the Fuel Section of the Society of Automotive Engineers affords another. In this country the recent extension of the British Standards Institution and the growth of the various co-operative research associations illustrate the same movement. The need for co-operation in the standardising of tests and testing methods has long been recognised. Professor Brame[1], in his presidential address in 1922, dealt fully with the history of the subject up to that time. During the last few years the Standardization Committee, over which Professor Brame still presides, has done useful work and enjoyed the co-operation of other interested bodies.

To our co-operation with the American Society for Testing Materials and the American Society of Automotive Engineers in the matter of evaluating knock rating of motor fuels, I have often referred. We hope that this will provide an active nucleus round which a larger international organisation will grow. There is a distinct tendency towards the formation of international co-operation in standardisation of materials and of testing methods. The International Standards Association has recently issued invitations to twenty-one countries to take part in an international effort. The secretariat of this has been entrusted to Committee D.2 of the A.S.T.M. in the person of Dr. Anderson. This body is wise in not attempting too much. It will confine its work to providing for international co-operation in standardising work, instead of attempting the promulgation of international standards. The adoption of a uniform standard international nomenclature is beset with so many difficulties that its realisation is a hope rather than an expectation. The adoption of international specifications presents a problem almost as difficult. The most hopeful line of progress is that of obtaining mutual agreement on methods of testing. Unless efforts are confined to this line, at least at first, little real progress is likely to result.

Although there is a definite tendency towards such international co-operation, the present position is somewhat paradoxical in that the spirit of co-operation seems to be obscured by a selfish competition in the matter of effecting the co-operation. Numbers of independent bodies are displaying interest in this subject to such an extent that co-operation may be retarded by their action.

[1] *J. Inst. Petr. Techn.*, 1922, **8**, 300-311.

Some of these embryo associations propose dealing only with special products, so that sectional treatment may lead only to confusion and result in delaying rather than accelerating the co-operation which is so necessary.

The old International Petroleum Commission has revived and decided to co-operate with the New International Association for Testing Materials. The Société de Chimie Industrielle, at its Paris meeting last October, formed a committee to consider the practicability of arriving at international methods. The Lubricating Oil Congress at Strassbourg last July formed a similar committee, and the World Power Conference is thinking of doing the same. There is much evidence of the desirability of international agreement, but decided lack of co-operation as to the means of effecting it.

There is much need for clarity on the subject of the fundamental units and their inter-relation, and of the physical constants used for the measurement of oil in bulk. That there is much confusion on this important subject appears from a perusal of the numerous books dealing with the matter. That there is some excuse for this state of affairs was soon found out by our special committee appointed to go into this question. There are even difficulties with the fundamental units themselves. Thus the imperial unit of capacity, the gallon, is defined as the volume occupied by 10 lb. of water at 62° F. weighed in air, but the International litre is referred to the volume of a kilo of water at 4° C. weighed in vacuo. Moreover, the fundamental unit of capacity, the U.S. gallon, is defined as the volume occupied by 231 cu. in., the U.S. inch being slightly longer than the Imperial inch if only to the extent of three parts in a million. There is, moreover, no definite statutory authority for the figures used for conversion of volume to capacity in the Imperial system. As this operation is a daily necessity wherever oil measurement in bulk is made, an accurate, or at least generally agreed, figure is certainly desirable.

The Standards Department of the Board of Trade tells us that the figure worked out by them is 1 cu. ft., equals 6·2288 (3) gallons. They claim that this equivalent has been worked out by the application of the latest experimental data available, but they acknowledge that this factor is not statutory. The weight of a cubic inch of water in grains was, however, laid down in the Weights and Measures Act of 1824. This was superseded later by an Order in Council of November, 1889, which specified that 1 c.c. of water weighed in air at 62° F. weighed 252·286 grains. The relation of the cubic foot to the gallon worked out from these data does not agree with that given above. Although this figure of 1889 is admittedly out of date, it is the last figure published with statutory

authority. Our standardising committee is struggling with such difficulties as these, but they hope before long to present their findings in the form of a report backed up by all possible authorities. The Board of Trade Standards Department and the American Bureau of Standards have signified their agreement. The committee will then turn their attention to the whole question of the measurement of oil in bulk, including the calibration of tanks, in which subject there are ample opportunities for useful co-operation by the many parties involved.

I have so far been speaking of co-operation within the confines of the industry, but I have in mind also co-operation on an extended scale between the industry and other industries or allied organisations which have some connecting link. For example, the history of the development of the gasoline engine during the last few years indicates plainly that avoidable mistakes have been made through lack of co-operation between the manufacturers of the engines and the manufacturers of the fuels on which the engines were to run. For example, while engines were developing in the direction of adaptability for gasolines of lower volatility, natural gasoline appeared in quantity and gasoline became more volatile. The combination of these two factors working in opposition brought about the absurd result that excellent engines could not run on excellent gasolines. As long as crude oils vary in character, and as long as new developments, such as natural gasoline cracking and hydrogenation appear, gasoline cannot be constant in quality in relation to time or place. While it is hard to make predictions, the oil producers must have some general idea as to the trend in the immediate future, which information would certainly be of great use to the engine designer and vice versa. The attempt to express anti-knock rating in terms of the percentage of a fuel of high value in a mixture of this with one of low value, although simple in principle, is proving to be hedged with many difficulties. It is now apparent that such comparisons hold only under carefully specified conditions in a definite engine. The lack of realisation of these limitations is giving rise to a great deal of loose talk about octane values. The need for engine manufacturers to co-operate with those carrying out the investigations in reasearch engine laboratories is thus daily becoming more obvious. A special committee of this Institution has been formed with such object in view, and is on the point of approaching the Institution of Automobile Engineers in this country. Similar co-operation with users and manufacturers of aero engines is also being established, as the problems connected with aero engines differ in some respects from those presented by the water-cooled car engines.

The advent of the high-speed Diesel engine is opening up quite a number of problems. In its present development these engines are decidedly selective in their fuel tastes. The gas oil which they favour is in much demand by the coal gas manufacturers and for the numerous systems using oil fuel for central heating. There is room here for co-operation, not only in the study of light fuels, but also in the direction of applying the heavier residual fuels. The joint meetings which are now being held and so well attended indicate that fuel users and fuel producers do see the necessity for working together. I may here mention the co-operation which has been established between our special committee for the investigation of mule spinners' cancer and the various organisations dealing with the investigation of this complaint. This disease, which is prevalent among the cotton mule spinners in the Lancashire district, has been ascribed, rightly or wrongly, to the effect of continuous contact with the spindle oil used for the lubrication of the mule spindles, to which the operators are necessarily, or perhaps unnecessarily, subjected. That this form of cancer is really attributable to the oil is, we feel, far from being definitely proved. However, as we felt that, whether the oil be to blame or no, we could offer assistance to the investigators by supplementing their medical and pathological knowledge with our available chemical knowledge of the character and methods of treatment of petroleum oils, we formed a committee, on which we have the advantage of two medical men long connected with the petroleum industry, to keep in touch with the work which is being done on this subject and to give what assistance we can. Progress is naturally very slow. Years must elapse before the various questions are definitely settled. It is too early to report any progress at present, although we have had indications which suggest lines of attack.

There has been much discussion lately on the subject of oil from coal by distillation or hydrogenation, and the question of a possible co-operation between the coal and oil industries has been raised. Should some form of liquid fuel be eventually produced from coal, then there would clearly be a good case for co-operation between the two industries in the matter of distributing the new coal oil. Such an arrangement would be of benefit to producers and consumers alike. The building up of any such complete distributing system as the oil companies already possess would be an unjustifiable expense. Indeed, in the United States, excessive competition in the provision of distributing systems has resulted in facilities for the sale of motor spirit far in excess of what is required. The same trend is obvious in this country too. But a closer co-operation than that necessary for economic distribution

is open to these two industries. Both industries produce gaseous and liquid fuels. The oil industry helps the coal gas industry in the United States by supplying natural gas of high calorific value as a blending agent to raise the calorific value of the coal and water gas. The coal gas companies have the distributing systems in the towns, the oil companies have the high pressure long distance distribution system. In the case of Chicago, for example, such co-operation has been established, and a pipeline from distant Texas supplies natural gas of 1000 B.Th.U.'s to the coal-gas companies of the city. Similar co-operation has long been effective in California.

Advantages may be, and indeed are being, derived by co-operation in the use of the liquid products, be they creosote or distillate oils or residual oils or pitches. Creosote, apart from its special uses, is being used as a furnace fuel, in admixture with petroleum oils. It is of value for reducing the viscosity of thick oils, although at the cost of reduction of calorific value. It is possible that it may find application as a fuel for internal-combustion engines.

The residual tars and pitches of the coal industry should not compete with the bitumens from petroleum in the widespread applications of road making. This is not the time to discuss their relative values. They are by Nature really allies, and in the opinion of many, show their qualities for road dressing best when blended. In Scotland and Ireland the use of bitumen and tar in admixture is well established and increasing. As the tar from vertical retorts is not as suitable as that from horizontal retorts, the increasing use of the former type gives the question of blending with bitumens greater importance. The question of the conjoint use of the two products is certainly worthy of close conjoint study.

One very important effort at co-operation has unfortunately been seriously set back by the present period of depression. I refer to the scheme for housing scientific and technical societies under a common roof, with certain common rooms and library. The present multiplication of scientific societies, with the accompanying overlapping of publications and running expenses, but without any overlapping of subscriptions, is certainly an undesirable state of affairs. It is to be hoped that as soon as better times come round this idea will be actively pursued and brought to effective fruition.

Our environment, both material and human, is undergoing a change. Science and its applications are exerting an ever-increasing influence on each and all of us. Modern developments in metallurgy, electricity and even apparel and food, bring products from distant lands into even the humblest of households. The spasmodic

occurrences of minerals of vital importance in restricted areas makes nations dependent on each other. We could not live alone if we wanted to. If the greater power of realising our desires which science gives us is to be a boon and not a bane, then it must be used constructively in co-operation and must diminish eventually to zero the part played by selfish competition, both individual and national. The co-operation of individuals which has made possible the existence of prosperous national communities must extend to the co-operation of these individual nations towards a larger community, involving ultimately the whole of mankind.

Vote of Thanks to the President.

Prof. J. S. S. Brame said he felt it a very great honour to be allowed to move a very cordial vote of thanks to the President for his most inspiring Address. As members knew, Presidential Addresses were not open to any discussion, but he was sure that Mr. Kewley had introduced into his Address so many inspiring thoughts in the matter of co-operation that all members would look forward very keenly to the publication of his Address in the Journal. He had very much pleasure in asking members to accord their heartiest thanks to the President for his inspiring Address.

The vote of thanks was carried with acclamation.

REPORTS ON THE PROGRESS OF NAPHTHOLOGY, 1930—1931.

Petroleum Geology.

By James Romanes, F.G.S. (Member).

In the two years which have elapsed since the last number of the "Progress of Naphthology" the oil industry has suffered, and is still suffering, the most difficult period of its existence. Little did anyone think, when some ten years ago a world shortage of petroleum was being seriously discussed, that the year 1931 would see American troops used to curtail the ever-increasing flood of oil. Naturally this over-production, and it is definitely over-production rather than under-consumption, has greatly checked the exploratory side of the oil business. Company after company has cut down its geological exploration to a minimum and confined itself to more or less routine work. There is, therefore, less in the way of striking geological discoveries to comment on, though steady progress in the science of oil geology has been made. Whoever is to blame for the present state of the oil industry, for once the geologist cannot be made the scapegoat.

In oilfield development work the changes most affecting the geologist are the greatly increased depth of wells and the much fuller information now obtained from them. Not only has the use of coring been greatly extended, but in the past two years the advantage of straight holes as against abnormally fast drilling rates has been realised, so that now the geologist may feel fairly confident as to where his cores have come from. The depth of wells to-day throws new problems on the geologist, such as the projection of folds and faults at depth, and the question of the effect of great depths on migration and concentration of oil.

It is impossible to do more than touch on some of the more striking work.

In the United States, in spite of over-production, proration and general financial gloom, many new fields have been discovered, while known fields have been increased in length, breadth and thickness. Of new fields the most striking are Kettleman Hills, the Oklahoma City field and the great East Texas Development from the Woodbine Sand; the latter, as will be referred to later, has interesting geological features and has claimed much geological attention. It cannot be denied that in America the geologist has far more feathers in his cap in the shape of oilfields developed on purely geological reasoning unaided by surface seepages than

in any other country. Whether this is due to American conditions, American geologists or American enterprise, it is hard to say, possibly a combination of all three, but it leads one to suspect that, with the now vast accumulation of geological experience and data on oil problems, any real incentive to spend money on geological exploration might have surprising results in other parts of the world to which comparatively little attention has been paid. In speaking of American oil geology mention must be made of Van Wiebe's book on "Oil Fields in the United States," primarily on account of the method of classification which he adopts. He divides his subject into eleven tectonic elements—e.g., the Appalachian Geosyncline Province, the Gulf Embayment Province, the Cincinnati Arch Province, etc. These he then proceeds to treat as regards detailed structures and stratigraphy. The method is a commendable and logical one, especially in such a country as U.S.A., where geographical classification is apt to leave the mind completely confused as regards the larger ideas.

Canada, and especially the Turner Valley area, has been the scene of much geological activity, though with less striking results. A large literature is accumulating on Canadian oil geology. In our own Journal we have had a contribution by E. H. Cunningham Craig,[1] discussing the probable origin of the Turner Valley oil. A structural paper on the same area has been contributed by A. J. Goodman,[2] and Theodore A. Link,[3] in an excellent paper, deals with the geological history and structure of the Alberta syncline in the light of the most recent drilling. Southern Alberta received full treatment in the Bulletin of the American Association of Petroleum Geologists, Vol. XV., No. 10, 1931, where fourteen papers by well-known geologists form the "Donaldson Bogart Dowling Memorial Symposium on Stratigraphy of Plains of Southern Alberta." There is little doubt that had it not been for the world depression an even greater activity would have been witnessed in Canada.

Our knowledge of salt domes has materially increased in the past two years, a valuable addition being J. V. Harrison's[4] excellent and detailed paper on the salt domes of S.W. Persia, a region of which little was hitherto known and one of extreme interest since Harrison claims a Cambrian age for the salt.

Donald C. Barton[5] contributes a paper on the Gulf Coast potentialities in the light of recent discoveries and deeper drilling, and

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[1] *J.I.P.T.*, 1931, **17**, 390–422.
[2] *Trans. Canad. I.M.M.*, 1930, **33**, 1505–1521.
[3] *Bull. Amer. Assoc. Petr. Geol.*, 1931, **15**, 491–507.
[4] *Q.J.G.S.*, 1930, **86**, 463–522.
[5] *Bull. Amer. Assoc. Petr. Geol.*, 1930, **14**, 1379–1400.

estimates the recoverable reserves at 5,500,000,000 barrels. Our Institution devoted two full meetings to papers and discussion on salt dome problems followed by a further more informal discussion. The papers included descriptions of salt dome conditions in the Gulf Coast, Persia, Arabia, Egypt and Germany. The evidence discussed was therefore world wide, and it may not be out of place to give briefly the final conclusions arrived at; these were as follows:—

1. That all the evidence points to the salt of salt domes being derived from normal sedimentary saline deposits.
2. That the flow of the salt is due to earth pressure.
3. That in the majority of cases, while tangential pressure may determine the orientation and initiation of the domes, the main force is due to weight of overburden.
4. That as regards the commercial accumulation of oil around or over salt domes, the action of the dome was purely tectonic and in no way connected with the origin of the oil.

In Europe, apart from one new discovery, there is perhaps nothing very striking to comment on. In Rumania the information yielded by deeper and better cored wells is leading to a fuller understanding of the complex geology there, and by general agreement the salt appears to be settling down to a Permian age, a happy compromise between the long held Miocene salifere theory and the Pre-Cambrian of Voitesti. Regarding the salt dome structure, evidence is accumulating to show that some of the so-called domes are "floating" masses entirely torn away from their mother horizons.

Germany has provided the one really striking new discovery, due initially, however, to an accident and not to the petroleum geologist.

About the middle of 1930 there occurred in a potash mine at Menteroda, near the Thuringian-Prussian frontier, an explosion due to the outburst of oil and gas in the lowest (1000 m.) galleries. As a result, small diameter holes were drilled down from this level, and at about 50 metres oil under very high pressure was struck. By this means, at the end of 1931, a monthly production of about 12,000 tons (90,000 barrels) had been attained, nearly doubling the previous German production. Apart from the importance of this new development to Germany, it is of peculiar interest to the petroleum geologist, as it is the first really commercial production of oil, outside of the American Continent, from the Palæozoic. The productive horizon appears to be a dolomite, probably equivalent to the "Stinkschiefer" underlying the Zechstein salt; as this is an integral part of the vast European Permian

basin, one would hardly imagine that this was the one and only spot where conditions for the formation and accumulation of oil occur. One may therefore expect that further Permian production will be obtained in Europe, and this inevitably leads on to the speculation as to whether Europe may not yet show commercial production from the Carboniferous or lower.

Before leaving Europe reference must be made to the publication of Vol. II., Part II. (2nd Edition), of Engler and Hofer's well-known publication, "Das Erdöl."[6] This is a most valuable addition to European Oil Geology, and fills a long-felt want, giving as it does a general outline and also much detail of the oil geology of European countries (excluding Russia). The work is a compilation by various authors, each dealing with the area in which he has specialised.

Turning to Australasia much geological exploration has been carried out, though no very conclusive results have been attained. The results of the prolonged and detailed geological surveys carried out by the Anglo-Persian Oil Co. in Papua and New Guinea for the Australian Government were published in the earlier part of 1931 and form a most valuable addition to the literature of petroleum geology.[7] This report, however, holds out little hope of the development of oilfields in these areas as the following extract from the able summing-up of the evidence by Mr. B. K. N. Wyllie shows: "This review ends, therefore, with a note of pessimism. Some possibilities have been admitted in regions not yet fully (or even partially) explored, but, in the main, the hopes entertained by the earlier geologists have been rejected." In Australia itself the long campaign of geological and drilling exploration has achieved a measure of success, as a number of small producing wells have been drilled near Lakes Entrance on the northern coast, but so far neither geological work carried out nor the drilling done seems as yet to give any definite indication of major oilfields.

Finally we have still with us that intriguing but elusive problem —the original and migration of petroleum. Much has been added to the literature, and though progress has been made we are still far from finality, yet it ought theoretically to be our starting point in the search for oil. One feels, however, that accumulated evidence is pointing more and more in certain directions, eliminating certain theories and narrowing down the field of research. Mackenzie Taylor, whose work is referred to in the 1930 "Progress

[6] "Spezielle Geologie des Erdöls in Europa ausschliesslich Russland," edited by J. Tausz, 1930.

[7] "The Oil Exploration Work in Papua and New Guinea Conducted by the Anglo-Persian Oil Company on Behalf of the Government of the Commonwealth of Australia, 1920–29," London, 1931.

of Naphthology," working along purely chemical lines, postulated an alteration of marine and fresh water conditions as necessary for the formation of oil, postulating further that these conditions were necessary alike for coal, oil shale and petroleum, and his further work on oil and coal has confirmed this. On general lines this in no way clashes with the view from the geological side that oil is at least in many cases associated with deltaic or shore line conditions.

The great East Texas field, already referred to, appears to be closely associated with the shore line conditions of a great island rising out of the Cretaceous sea. Walter Kauenhowen, in two papers,[8] comes to conclusions closely agreeing with the above, namely, that oil formation shows a marked palæographic distribution and that it requires the altercation of marine, brackish and fresh water conditions. Further, he concludes that coal and oil are mutually exclusive. J. E. Hawley drives another nail in the coffin of the theory that oil formation may be due to extreme pressure on organic material. From experimental work he concludes the formation of oil from organic or even kerogenous material is not proven.

The whole question requires the closest possible co-operation and collaboration between the geologist and the chemist, and would form an intensely interesting subject for a collection of papers from both sides followed by unlimited discussion.

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[8] *Deut. Geol. Geo. Z. Abl.*, 1929, **80** (4), 521–534; *Petroleum*, 1930, **26** (6), 174–178.

Oilfield Practice.

By A. Beeby Thompson, O.B.E., M.I.Mech.E., M.Inst.M.M., F.G.S. and Ashley Carter, A.M.I.Mech.E. (Members).

Although no striking innovation in oilfield technique has been witnessed during 1930-1931, wonderful progress in mechanical appliances and metallurgical problems must be recorded. Perhaps the most noteworthy achievement on the drilling side was the successful completion of a well exceeding two miles deep in Mexico in face of exceedingly difficult obstacles. That this was done with standard machinery and equipment without recourse to specially heavy plant speaks wonders for the quality of modern oil well material. Proof that the cable driller has not lost his art was demonstrated by the completion of a well at Badger Basin, Wyoming, to a depth of over 8700 ft., when flowing oil was struck.

The ever-increasing depth to which wells are being drilled is leading to higher derricks up to 164 and even 175 ft. with 32 ft. square base, so that drill-pipes can be made up in stands of six joints, thereby hastening the process of raising and lowering the bit. By some it is claimed that any advantage in longer stands is more than offset by the difficulty of manipulating such long lengths, especially of the smaller sizes of drill-pipe. In Oklahoma City field one of the writers saw fourbles raised and lowered at the almost incredible rate of one stand per minute, when using twin engines and high pressure (250 lb.) steam.

Perhaps one of the noteworthy advances of 1931 has been the scientific construction of derrick foundations and cellars in concrete so designed that easy access can be obtained to casing-head fittings and control devices safely housed in concrete chambers below the derrick floor. No very extensive use has been made of the automatic feed of the Hild and Haliburton types, partly on the score of price, but mainly owing to the striking improvements in drilling with ordinary rigs when provided with weight records, tachometers and other devices for guiding the driller in the feed of the bit. Several appliances have been introduced to regulate the feed without the necessity of replacing normal drilling equipment. One device automatically releases the brake of the draw-works through the medium of gear set in motion as a result of electrical contacts between the weight recorder and the gear. Another regulates feed by a steam operated auxiliary hoist on the drum of which the dead end of the drilling line is coiled. This operates through arrangements connected with the weight recorder. Both rely entirely on some working weight arbitrarily fixed by the driller, so

that it is still left to human judgment to determine a weight on the bit which will ensure the maximum safe rate of progress when operating in different strata.

The depressed state of the industry has been, to some extent, responsible for the delayed introduction of the hydraulic feed rotary, which attracted considerable attention as well as favourable comment. Several hydraulic feed drills of clever design and fine workmanship are on the market incorporating features which appeal to all engineers, but unless exceptional difficulties are suspected the expense is sometimes questioned. One new drill of the hydraulic feed type, combining all the main features of the mining drill is now on trial, and if it fulfils expectations and can be produced at a cost comparable with standard plant, it is likely to command attention. Some advance has been made in semi-portable rotary equipment, where the various units are carried on wagons with caterpillar wheels. They are designed for moderate depth of, say 2000 to 3000 ft., and can be driven by either steam, electric power or gasoline engines. Serious consideration is also being given to drilling deep wells at an angle in order to reach beds inaccessible by vertical holes, or to strike oil-carrying fissures known to traverse strata in a nearly vertical angle. Satisfactory results have been achieved in Mexico by such work in areas where payable oil depends upon striking fissures, which cannot be located by means other than drilling.

Drilling progress has been improved more by the general recognition of the ills which accompany crooked holes and the means of detecting their occurrence than by any recent event. The survey of holes at regular intervals, and the insistence of straightening up when deviation is measured has revolutionised rotary drilling and removed at one stroke the majority of the troubles which faced the driller. Few wells are now drilled to depths in excess of 2000 ft. without a check with some form of declinometer for verticality, and where more precise data are wanted directional apparatus is used. Analyses of declination results show that wells drilled in low dipping strata practically always deviate up dip, whilst in steep dipping formations the tendency is to drift down dip.

Next in importance to straight hole drilling has been the advance in preparing and reconditioning mud. Natural muds are now frequently doctored with chemicals and preparations to add weight and adjust viscosity when drilling in high pressure strata or badly caving formations, and the difficulty of effecting the separation and deposition of cuttings and sand particles from muds of nearly the same specific gravity as the strata is being overcome by the use of vibratory screens and classifiers. This innovation has resulted in a great reduction of pump wear and power consumption.

In a few cases separation by centrifuge has been successfully accomplished, but it may only be rarely necessary to clarify the mud to such a degree of separation as it effects.

Central mud plants are being more often used where the strata being drilled will not yield a suitable mud, the prepared product being pumped in pipe-lines to points of use. Properly reconditioned mud is said to be better than new mud, and its treatment and reuse often saves much trouble and expense in its disposal.

Deeper drilling, with the consequential higher gas and water pressures, which at times exceed a hydrostatic pressure based on present-day land levels, have enforced the occasional use of snubbing apparatus, flush jointed drill-pipe, and locks through which the tools can be inserted and withdrawn in safety. Quite a number of ingenious blow-out preventers have been designed to meet emergency conditions and work of the above-described nature.

Deep drilling is leading to the discovery of new troubles every year, but one of the most difficult and perplexing problems is that of dealing with variable pressures. In some fields there is not a progressive and nearly regular pressure gradient with depth, but pressures both above and below those due to a hydrostatic head are met with. Some strata absorb fluid, others expel fluid when using a circulating medium of some definite weight, and although it is often possible to plug absorbent formations and neutralise high pressures by using heavy muds and other materials, it is not always possible. These troubles, combined with high temperature waters, introduce grave drilling problems. Apparently open fissures occur in some deep strata and progress can only be made by drilling under a controlled pressure with selected mud, which just balances the deep hydrostatic conditions. Occasionally two totally different pressure conditions may be exposed in the hole at one time, thereby introducing further complications.

Fishtail bits are steadily giving way to drag bits with several wings, thereby avoiding the shocks inseparable from fishtail work. These have been rendered possible by the advance made in repair work by means of building up the wearing parts with hard metal facings or inserts of Tungsten carbide and other carbon substitutes. Only one bit, the Zublin, has made any radical departure from conventional design, and this has given marked satisfaction in some fields.

Coring has now become a routine operation in most oilfields when interesting strata are being pierced or evidence of dip is required, and there are many very satisfactory core bits on sale. There are now on the market several serviceable cable-coring appliances which will take sample cores from all but very hard rocks. For very hard rocks, core bits of the roller, rock type are used.

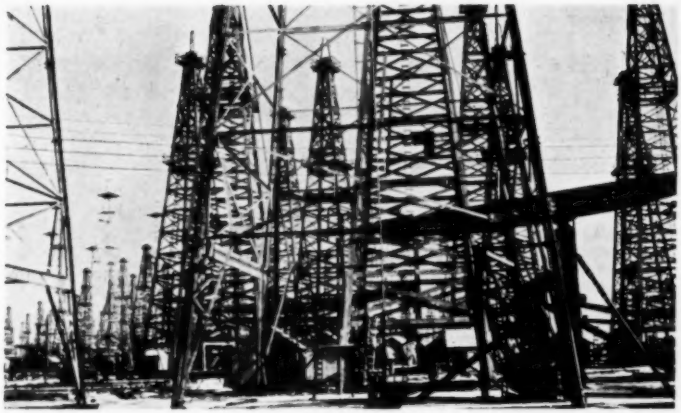

FIG. 1.

SPINDLE TOP, TEXAS, NOV., 1930. NEW DEEP FIELD. SPIRITED OFFSETTING, DEEP FIELD, 1930-31.

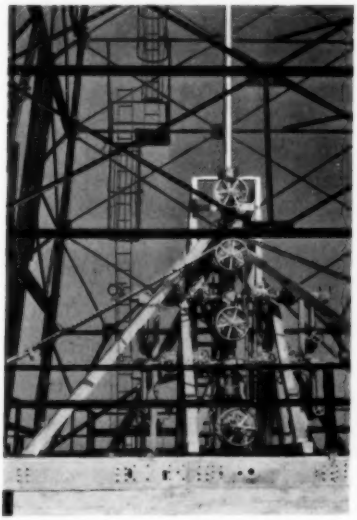

FIG. 2.

KETTLEMAN FIELD STANDARD WELL, 7000 FT., OCT., 1930.

FIG. 4.
REED COLLAPSIBLE BIT, TEXAS.

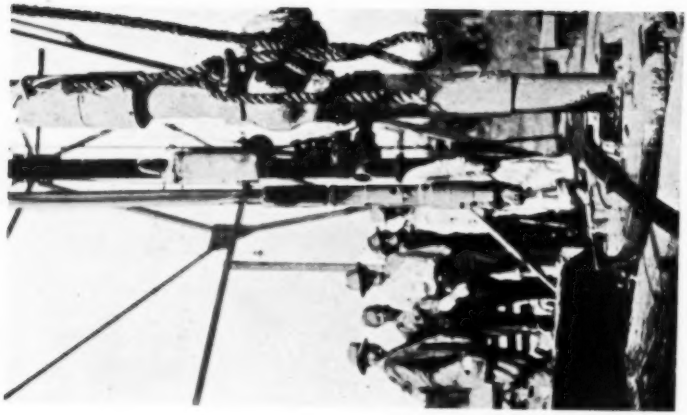

FIG. 3.
REED COLLAPSIBLE BIT, TEXAS.

REED COLLAPSIBLE BIT, TEXAS.

FIG. 5.

GAS PUMP ON WELL OF STANDARD OIL, INGLEWOOD, CALIFORNIA, 2500 FT.

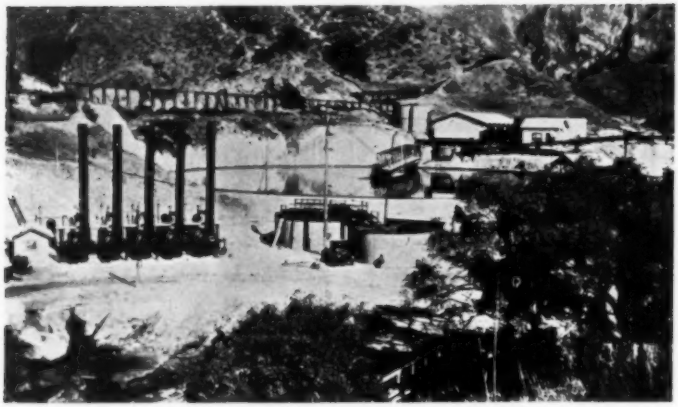

FIG. 6.

ASSOCIATED OIL CO. MUD PLANT, VENTURA FIELD, CALIFORNIA.
RECONDITIONING MUD.

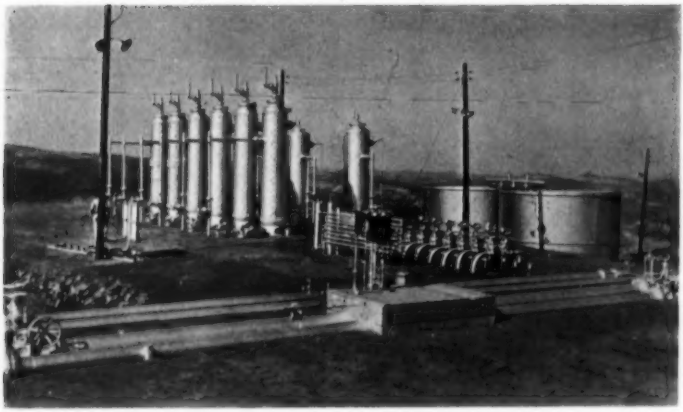

FIG. 7.

KETTLEMAN HILLS. SEPARATORS AT STANDARD OIL WELL, CALIFORNIA, OCT., 1930.

Worthy of mention is the wire-line, rotary, drilling bit which has been successfully used in deep Texas wells. By using full-way tool joints the expanding bit can be raised and lowered inside the drill-pipe itself. The saving of time is in consequence very considerable, as worn cutters can be quickly replaced. The tool provides for the use of a core bit as well as a straight fishtail. As many practical drillers incline to the view that cavings, and even blow-outs, are largely due to the suction set up when lifting the drill-pipe, one important danger is largely eliminated by the use of such a bit. This drill has been successfully used in deep wells and for structure core-drilling in the Gulf Coast area of Texas.

An event of unique interest in oilfield work was the striking of oil in 1931 in the Potash Mines of Thuringia, Germany. Following an outburst of oil into the workings at 3000 ft. the floor of the mine was explored by drilling and at a further depth of 150-200 ft. flowing oil was struck in a limestone of Permian age. A large number of wells (about 80 it is said) $1\frac{1}{2}$ in. to 3 in. diameter have been drilled giving a yield of about 12,000 tons of oil per month. Modified rock drills are used. Some of the wells are drilled vertically, others at an angle, and the oil flows into separators, where the gas and oil can be independently dealt with and pumped to the surface. Naturally, such operations call for the exercise of great care, and already a serious explosion and fire have been reported.

On the production side striking improvements have been introduced for dealing with high-pressure wells which flow naturally, and in the methods of extracting oil from deep wells. High-pressure fittings and valves are now manufactured to withstand pressures up to 5000 lb. if called upon, including blow-out preventers for use if the wells get out of hand before everything is ready. With the use of carefully conditioned mud and pilot-hole drilling and coring when interesting strata are being penetrated, it is only occasionally that wells cannot be kept subdued until all flow fittings are fixed and the Xmas tree with beans fitted in place. The deep wells of Kettleman Hills, California, are regularly completed at 7000 to 8000 ft. without any loss of oil, and the finished Xmas trees are painted in aluminium or other paints with no trace of oil visible.

Grave risks were taken by operators in the Oklahoma City field, where, in the desire to secure a maximum output for purposes of high pro-rating, many wells were allowed to flow at such a high rate that sand cut the control fittings to a dangerous extent. Numerous wells could be seen where high-pressure valves and fittings had been cut and scored until leaks developed, and it was due more to luck than good management that operators were able to return and kill the well with mud before the surface fittings were blown away.

The deep high-pressure wells of the Moreni, Gura-Ocnitzei and Boldesti fields of Rumania are being regularly brought in under complete control, but the dangers of any slight mishap are illustrated by a Gura-Ocnitzei well, which got out of control when lifting the tools before surface protective measures had been taken. At first the drill-pipe and later the casing were ejected from the hole and a large crater was formed, whilst oil was sprayed over the countryside for miles. Being a highly paraffinous oil, it clung to the foliage of trees, and in the winter the curious effect was witnessed of the forest trees retaining their foliage protected by a covering of wax. The well was killed by pumping water against a pressure of nearly 1500 lb. per sq. in. in a near-by well, otherwise a serious situation would have arisen.

The fire at the Moreni well was extinguished in 1931 after burning for about two years. Only the most approximate estimate of gas losses can be made, but they may have reached something of the order of 30,000,000,000 cu. ft., and the distance that came under the influence of the well is probably measurable in kilometers. Although extinguished by smothering with mud and earth thrown into the crater by blasting, gas still continues to issue from many funnels connecting with the tunnels. The dangerous gas area is fenced, but it is doubtful whether in its present state it does not constitute a greater danger than when burning.

As soon as the period of natural flow ceases, the deep wells are almost without exception put on gas lift, and this is left to function so long as the production is satisfactory. The next process is more perplexing, as pumping at depths exceeding one mile calls for considerable care and great expense. As a rule the end of the gas-lift period leaves the well with a fair static head, and recent developments are in the direction of following up with intermittent displacement systems.

Where the fluid conditions are satisfactory, oil properties can be automatically worked from a central station or as units by a skilful adaptation of gas-lift displacement apparatus, and this has certainly been the most important innovation of recent years. The size of chamber and its depth of insertion must be carefully calculated to suit the available pressures with the combination of tubing in use. Where high-pressure gas is available, compressors are unnecessary, either for direct air-lift or for displacement working.

Without question, means of pumping deep wells will be found, especially now that they are drilled more nearly vertical, but the expense and danger of removing pump plungers and barrels after wear is a serious objection to their use.

The use of improved high carbon or alloy steels subjected to careful heat treatment, coupled with accurate balancing on the

surface, is greatly simplifying deep pumping operations. An interesting deep-well pump under test at Inglewood, California, is of the long stroke type, where the vertical movement is effected by gas pressure acting on rams. The speed of working and length of stroke can be adjusted to suit conditions at each well.

The very low price ruling in 1931 for crude oil has not favoured activity on low grade properties, and little has been done in the way of measures for abstracting the dregs of partially depleted oilfields. Most operators have concentrated on a policy of deep drilling with high initial production, but with crude oil at a price of about 5s. per ton at the well, as in Rumania, it has taken a very large output to pay for wells costing about £10,000. In protected markets, the small-producing well can still be worked at a profit when the operating costs are low and multiple pumping can be carried out, but they will not bear high overheads.

Considerable attention is being given to the question of unit operation, with which few object in principle. It is only upon the ways and means of effecting its application that opinions differ. Much has been accomplished in some of the United States oilfields by mutual goodwill when great interests were at stake, but in other places competitive drilling still proceeds with its attendant deplorable waste. Closely following stringent regulations in Rumania for the prevention of gas waste, we have the spectacle of more gas waste than ever before. Gas flares illuminate the country for miles around the major deep fields of the country.

Restrictive measures have been enforced in the escape of gas in the Turner Valley, Alberta, where the volume escaping unused into the atmosphere was estimated at 560,000,000 cu. ft. a day in June last. Official attempts to enforce restrictive measures in East Texas led to military intervention, which for a time brought production almost to a standstill. The legality of coercion by State action on oil producers has been questioned, and is likely to be decided in the Courts. The temporary reduction of output on a difficult market was beneficial.

Scientists are ever seeking uses for surplus gas and waste products. A recent development is butane extraction, which is too light to be left in commercial gasoline and too heavy for pipe-line gas, as it gives trouble by condensing in the mains. Isolated and stored in pressure tanks, it forms an admirable product for air carburation in districts not supplied by gas or electricity.

Present Trends in Oil Pipe Lines.

By R. P. Bascom.

The present tendency in pipe line construction is for engineers to specify thin wall, high strength pipe made by one of the new processes which have been perfected by pipe manufacturers during the last two years.

Formerly, most of the pipe used in oil pipe line construction was made by the lap-welding process. This pipe conformed to specifications covering thickness, weight per foot, chemical and physical properties, which had been in use for years, and which were codified under the American Petroleum Institute specification for lap-welded pipe. Occasionally, seamless pipe was used for oil lines, but the specification for this product did not vary greatly from the lap-welded pipe specification.

During the last two years several manufacturers have turned their attention to the production of line pipe by new processes and manufactured to new specifications. These new processes consist, in general, of cold working the steel sheets into shape, joining the longitudinal seams by electric welding, and finally bringing the pipe into round and straightening by additional cold working.

This new pipe is, in most instances, made from high carbon high manganese steel sheets which are thinner and of a less weight per foot than the lap-weld specification for the same diameter pipe.

A comparison of the specifications for the two kinds of pipe is given below :—

Size.	Lap welded. 10 in.	New pipe. 10 in.
Carbon	—	0·20 to 0·30%
Manganese	0·30 %	0·40 „ 0·60%
Sulphur	0·06 %	0·05 %
Phosphorous	0·045%	0·04 %
Elongation in 8 in.	22·000%	30·000%
Elastic limit	25,000%	38·000%
Ultimate strength	45·000%	60·000%
Weight per foot	40·483 lb.	31·201 lb.
Wall thickness	0·365 in.	0·279 in.
Hydrostatic test	1000 lb./sq. in.	1000 lb./sq. in.

It is interesting to note that while analyses made from finished lap-welded pipe will conform very closely to analyses made from the skelp and ladle steel, analyses made from the finished thin wall pipe show a reduction in elongation and an increase in the elastic limit and ultimate strength. This change is brought about by the cold working which the sheets undergo and the final forming operation which stresses the metal beyond the elastic limit.

One manufacturer is at the present time making pipe with a wall thickness of $\frac{1}{8}$ in. The steel has an elastic limit of approximately 70,000 lbs. and an ultimate strength of 110,000 lbs. The carbon content is from 42 to 52. The pipe is coated at the mill with an enamel covering. All bends which are to be used with this pipe are made in the factory and welded in place in the pipe lines.

Some changes in field laying technique are necessary to overcome the resistance to bending introduced by this high carbon, high manganese, high strength pipe.

Thin wall electrically welded pipe is made up to 45 ft. in length, which materially adds to the speed of construction. The pipe is furnished either in plain end scarfed for welding, or with bell and spigot or with double bells, the double bell pipe being joined together by a short piece of pipe known as a chill ring which is inserted in the two bells and forms a foundation for the circumferential weld. The use of the chill ring is confined to large diameter pipe, where the heat of welding expands the pipe to such a degree, that it is difficult to close the weld.

Chill rings are also used to some extent with plain-end pipe made by the cold-forming process. This method of manufacture produces a product which is uniformly round to very close tolerance, and in consequence the chill rings may be inserted into the ends of the pipe without expanding the pipe ends for the reception of the chill ring.

The use of thin wall pipe for underground lines has given added impetus to the study of corrosion problems. Pipe lines built from standard weight pipe, both painted, and unpainted, have been in the ground for years, and engineers, due to their lack of knowledge of the proper method to use to protect pipe lines against corrosion, are somewhat reticent to accept thin wall pipe for underground service even though they recognise that the added weight of steel in standard weight pipe is a poor substitute for proper protection against corrosion.

At the present time the industry is divided into two schools, those who believe that pipe lines should be painted and those who feel that no definite value can be assigned to protective coatings. In an endeavour to answer the question, "Are protective coatings worth their cost," tests are now being conducted by the users of protective coatings and the manufacturers of coatings. The tests are conducted and supervised by the Bureau of Standards of the Federal Government. It will be a long time before anything definite is determined by these tests.

Meanwhile, the problem of corrosion is being attacked from another standpoint. The presence of electric currents on underground pipe lines has been recognised for some time. These currents

are of three kinds—currents produced by induction, stray currents picked up by the pipe lines, and currents generated by the lines themselves. Stray currents which produce electrolysis of the lines are generally found by their rapid action, but the results produced by self-generated currents, sometimes augmented by stray currents, are slower of action and difficult of appreciation. The Bureau of Standards is now experimenting to determine the presence of earth currents, their amplitude and direction. Present experiments indicate that corrosion generally takes place at the point where these currents discharge from the pipe, and that these points of corrosive action are generally associated with a soil of high conductivity. It is hoped that in a short time proper instruments will be available whereby the soil in which the pipe line is to be buried can be surveyed for areas of high conductivity, and that the protection of the pipe in these areas will accomplish the desired result. It has been pretty generally proven that protective coatings fail for mechanical reasons, and in consequence soil stress has become recognised as one of the factors which must be reckoned with in pipe protection.

Thin wall pipe is sometimes painted in the mill, wrapped with tar or asbestos felts, and shipped to the job ready for laying. Considerable damage is done to the protective coating in laying the lines. To overcome this feature, a very simple machine has been devised for field wrapping pipe lines.

In the construction of pipe lines, the welded joint has almost entirely displaced the threaded and coupled joint. The circumferential weld is made by either the electric or oxy-acetylene process. The electric weld has been improved so as to now be equal to the oxy-acetylene weld.

During recent months, a new technique has been developed for oxy-acetylene welding. The new process employs a welding flame in which there is an excess of acetylene. As the pipe is heated, the steel absorbs carbon from the flame, and, as the carbon is absorbed, the melting point of the steel is lowered. This process causes the surface of steel to melt very quickly. As fast as the surface of the steel is liquefied, the welding rod is melted into the scarf with but little breaking down of the pipe wall. This process is much faster than the old method. It is claimed that satisfactory circumferential welds can be made in one minute of time for each inch of pipe diameter. Actual practice shows that this time estimate is liberal. At the present time, the technique for this new process is not complete inasmuch as the success of the weld depends upon exact co-ordination between the welder and his helper who turns the pipe, and upon the exact amount of space allowed between the

ends of the pipe to be welded. However, the new process bids fair to revolutionise the welding art, and to add considerable speed to pipe line construction.

The use of electric motors in pipe line pumping stations continues to grow as power transmission lines are built. The induction motor is the prevailing favourite, due to its great reliability. Some installations of synchronous motors have been made, but, as no allowance is given by the suppliers of electric energy for power factor, it is doubtful if the few points of added efficiency justify the high cost and more elaborate installation.

One installation of a completely automatic pumping station has been made. The station is operated by remote control through a system of electric relays which open and close valves, start and stop pumps, and signal the accomplishment or failure to accomplish any pre-determined operation.

American Refinery Technology.

By Benjamin T. Brooks, Ph.D., F.C.S. (Member).

Any review of American refinery technology in the last two years should certainly take note of the fact that the severe business depression of this period has shown that the petroleum industry is one of the world's most stable industries, so far as consumption of petroleum products is concerned. In 1931, when the steel industry in the United States declined to a minimum of 25 per cent. of its rated capacity, the consumption of petroleum products in the United States not only held its own, but showed a slight increase. During the year 1931 there was a substantial decrease in crude production, 56 million barrels, due to pro-ration measures, the actual production being estimated as 46 per cent. of the easily attained potential. Yet, notwithstanding this fact, and a general decrease in stocks of crude and refined products, the industry suffered record low prices for its products.

The more salient changes in refinery practice during the period under review were as follows :—

Gases.

Frolich and Wiezevich[1] have contributed a general review of the possibilities of chemical utilisation of refinery gases. The general practice is still to burn the gas as fuel, and they call attention to the fact that compared with 13,000 B.Th.U. coal at $4.50 per ton, refinery gases have a fuel value of about 17·3 cents. per million B.Th.U. The only chemical utilisations of cracked oil gas thus far established on an industrial scale are the manufacture of glycols and related derivatives and a series of alcohols, including ethyl alcohol. The manufacture of synthetic ethyl alcohol on a scale of about 10,000,000 gallons annually, by one company, has established itself during a period of very low priced molasses alcohol. The manufacture of a mixture of methanol and formaldehyde has been carried out on an industrial scale for several years, incidental to the purification of natural gas, but the installation of the process has not been further extended. Sullivan[2] and his co-workers have shown that the polymers of the gaseous olefins obtained by the action of aluminium chloride are poor lubricants. It is reported that a process has been developed for polymerising the ethylene, propylene and butenes in cracked gas to gasoline hydrocarbons, which is economically satisfactory when the gas is rich in these olefins and gasoline commands a good price, but details have not been published.

[1] Frolich and Wiezevich, *Ind. Eng. Chem.*, 1932, **24**, 13.
[2] Sullivan, Voorhees, Neeley and Shankland, *Ind. Eng. Chem.*, 1931, **23**, 604.

The conversion of refinery gases and particularly the ethane, propane and butane fractions of natural gas, into a motor fuel rich in benzole, by pyrolysis, has been the subject of extensive investigation,[3] but these developments have not resulted in commercial operation and in most cases have been definitely abandoned.

The use of gas oil for gas making has naturally been affected by the steadily increased demand for such oil for cracking to gasoline. The artificial gas industry has partly compensated for this change by the greatly increased use of natural gas transported long distances through welded high pressure lines. The cost of such long distance transportation of gas has been given as 2·5 cents. per 1000 cu. ft. per 100 miles. Refinery gases are also being used to an increasing extent, and propane and butane, shipped as liquid in pressure tank cars, is being used, mixed with air, in an increasing number of small towns. Oberfell[4] has given an excellent review of the liquefied gas industry, which showed an increase of 58 per cent. in 1931. Liquid propane and butane is available in quantity at about gas oil prices, and the plant required for its conversion to a mixed air-gas is very simple.

Another important substitution for gas oil is the satisfactory use of heavy bunker fuel oil for gas enriching purposes. One gas plant on the eastern seaboard has used 1,000,000 barrels of such heavy oil in one year.[5]

Gasoline.

In the recovery of gasoline from refinery gases, two processes have come into use for the preliminary removal of hydrogen sulphide, *i.e.*, the Koppers process and the Girdler process, the latter using an aqueous solution of di- or tri-ethanolamine. In both processes the solutions are regenerated by boiling, practically pure hydrogen sulphide being evolved[6]. Tri-ethanolamine is also employed to remove CO_2 from the hydrogen gas used in the hydrogenation process developed by the Standard Oil Company of New Jersey. One plant uses the amine to remove CO_2 from the flue gases from the combustion of natural gas, the CO_2 thus separated being manufactured into solid CO_2 ice; sufficient power is generated by burning the gas under in a steam plant for all the power required in the ice plant. The almost universal installation of gasoline recovery plants in refineries is given as one of the causes of the reduced demand for natural-gas gasoline.

[3] Podbielniak, *Oil and Gas J.*, 14.5.31, **29** (52), 22; Smith, Grandone and Rall, *Nat. Petr. News*, 28.10.31, **23** (43), 69.

[4] Oberfell, *Oil and Gas J.*, 21.5.31, **30** (1), 67.

[5] Foster, *Nat. Petr. News*, 3.11.31, **23** (44), 15.

[6] Girdler Process, U.S.P. 1.783 901.

Increasing importance has been given to the octane number of motor fuels, and cracked gasolines of very high octane number are now regularly obtained from a variety of crudes and the practical necessity of producing market gasolines of high octane rating has led to the installation of cracking or "reforming" units for the conversion of straight run gasolines of low octane rating to so-called reformed gasoline of high octane rating. Egloff[7] has given the following results obtained by cracking a wide variety of oils, including several of light paraffin type. In the cracking or "re-forming" of gasoline, one company uses a De Florez furnace, heating the gasoline to 925° F. at about 1000 lb. pressure, obtaining a recovery of 86 to 88 per cent. of gasoline of high octane number from a straight run paraffin-type gasoline.

TABLE I.

Octane Numbers of Cracked Gasolines from Various Charging Stocks.

Charge. Crude oils.	A.P.I. grav. of charge.	% of charge.	Octane number.	Cracked fuel oil. %	Gas and loss. %
Refugio, Texas	23·2	53·0	91	31·7	15·3
Santa Fe Springs ..	32·8	63·6	77	24·7	11·7
Joiner, Texas	37·9	69·4	70	22·6	8·0
Lost Soldier	29·4	59·9	79	35·7	4·4
Gasoline and Naphtha.					
Pennsylvania	52·7	84·4	76	4·8	10·8
Kerosine.					
Pennsylvania	46·1	81·2	75	8·5	10·7
Mid-Continent	39·1	69·2	81	11·7	19·1
West Texas	36·4	65·4	89	13·2	21·4
California	38·3	74·6	77	9·3	16·1
Santa Fe Springs ..	35·4	67·7	78	17·7	14·6
Gas Oils.					
Mid-Continent	35·3	65·2	80	15·1	19·7
Coastal	28·5	61·0	90	18·3	20·7
Fuel Oils.					
Mid-Continent	24·3	56·4	76	37·6	6·0
Oklahoma City	30·6	66·5	74	27·8	5·7
Kansas	26·2	61·0	75	29·0	10·0
Van Zandt, Texas ..	24·3	61·8	71	32·3	5·9
Joiner, Texas	27·6	53·9	74	35·4	10·7
California	17·8	38·9	79	61·0	0·1
Santa Fe Springs ..	19·8	40·9	75	51·3	7·8
Kettleman Hills ..	28·3	58·6	80	31·0	10·4
Pennsylvania	39·5	70·5	76	11·0	18·5
Kentucky	23·4	55·1	76	44·0	0·9
Lost Soldier	28·9	56·1	80	34·4	9·5

The octane numbers noted in the above table probably go far to explain the fact that vapour phase cracking has made little

[7] Egloff, *Nat. Petr. News*, 17.2.32, **24** (7), 31.

headway in the last two years. Vapour phase cracking continues to be practised by the Pure Oil Company, which company uses the Gyro process in five plants, by the Lubrite Refining Co. at St. Louis, where the C. J. Pratt process is operated, and by the Shell Company at East St. Louis, where the process of the Petroleum Conversion Corporation is used. The difficulties of refining the highly cracked gasoline produced by vapour phase refining appear to have been overcome by the Pure Oil Company by passing the crude cracked distillate in liquid form under about 1000 lb. pressure through a bed of fuller's earth at about 600°–650° F. The Lubrite Company refines the cracked distillate by rapidly treating with 66° sulphuric acid, the sludge being quickly removed, continuously, by centrifuging. In re-running the treated cracked distillate, a small amount of soda ash solution is fed into the gasoline stream to neutralise the SO_2 liberated during the distillation.

The most significant change in cracking methods in the last two years has been the large number of De Florez furnaces installed, 82 of these furnaces having recently been put into operation. This type of cracking furnace has already been described in previous reports.

An increasing number of cracking installations have included the Gray system of refining the gasoline with fuller's earth in the vapour phase. When equipped with a bubble tower, these combined units produce refined end point gasoline continuously from the cracking unit. Cracked gasoline of 70–74 octane number is refined by the fuller's earth method to 25+ colour, 10 mg. of gum and without decrease in octane number.

Concentrated solutions of zinc chloride, 85 per cent., used hot, are employed on the Pacific Coast for refining cracked gasoline, the method having been developed by Arthur Lachman.[8]

Two commercial size high pressure hydrogenation units have been in operation since the summer of 1930. The results have been described by Haslam and Bauer.[9] In connection with gasoline it is of great interest to note that gasoline has been so produced having octane ratings as high as 95, and with blending characteristics, equal to pure benzole. One of the peculiar characteristics of gasoline so produced is that the heavier higher boiling fractions have the best anti-knock qualities, whereas with cracked and straight run gasoline the anti-knock rating decreases with rising boiling point. One of the results of the hydrogenation process is the elimination of sulphur as hydrogen sulphide, the gasoline thus made averaging less than 0·03 per cent.

[8] Lachman, *Oil and Gas J.*, 12.11.31, **30** (26), 30.

[9] Haslam and Bauer, *Refiner*, Feb., 1931, **10** (2), 110; Haslam and Russell, *Ind. Eng. Chem.*, 1930, **22**, 1030.

Lubricating Oils.

The past two years have seen a very widespread installation of pipe still units operating under a vacuum for the production of lubricating oils of a wide range of viscosity. The manufacture in this way of lubricating oils of high viscosity has largely done away with the necessity of using heavy undistilled bright stocks to get viscosity, and many refiners manufacturing heavy bright stocks have been left with large accumulated stocks of this type of oil. Figure 1 shows two units having a combined daily throughput of 28,000 barrels of crude, the atmospheric pressure stage taking off streams of gasoline, naphtha, kerosine and light gas oil, the vacuum stage yielding heavy gas oil, wax distillate, overhead cylinder stock and flux bottoms. The entire unit stands on a plot, 220 ft. by 144 ft. The development in the last two years has been almost wholly along the line of vacuum distillation from pipe stills, the special methods such as the use of mercury vapour, used by one company, and diphenyl by another company, as indirect heating media, having not been further extended.

At the Wellsville plant of the Sinclair Refining Co. a unit was built in 1930, having a daily capacity of 7500 barrels, yielding seven cuts from a 155 ft. tower. The streams are regulated by De Florez remote control valves.

Due in part to exacting conditions of aeroplane lubrication, there has been constant effort made to improve the cold test of lubricating oils, particularly of the more viscous oils. Lederer and Zublin[10] have called attention to the fact that when wax is removed by the centrifuge method from oil diluted with naphtha, the pour test of the resulting lubricant is from 30° to 50° F. higher than the lowest chilling temperature attained in the process. Bright stocks having a cold test of 0° F. to 10° F. produced by a process described by E. R. Lederer[11] have been on the market since about 1927.

The secret of making such low cold test bright stock appears to be mainly careful supervision of each step in the process, rather than merely the use of excessively low chilling temperatures.

The effect of so-called inhibitors in interfering with the crystallisation of wax has been the subject of considerable study, and generally the effort has been to remove them so far as possible. However, Davis and Blackwood[12] have shown that by the addition of 1 to 1½ per cent. of synthetic hydrocarbon, made by coupling

[10] Lederer and Zublin, *Oil and Gas J.*, 25.12.30, **29** (32), 64.
[11] Lederer, U.S.P. 1,803,941, 1931.
[12] Davis and Blackwood, *Oil and Gas J.*, 12.11.31, **30** (26), 46; U.S.P. 1,815,022.

a chlorinated paraffin wax with an aromatic hydrocarbon such as naphthalene, the crystallisation of the wax is inhibited to a very marked degree, the effect being to convert, for example, a

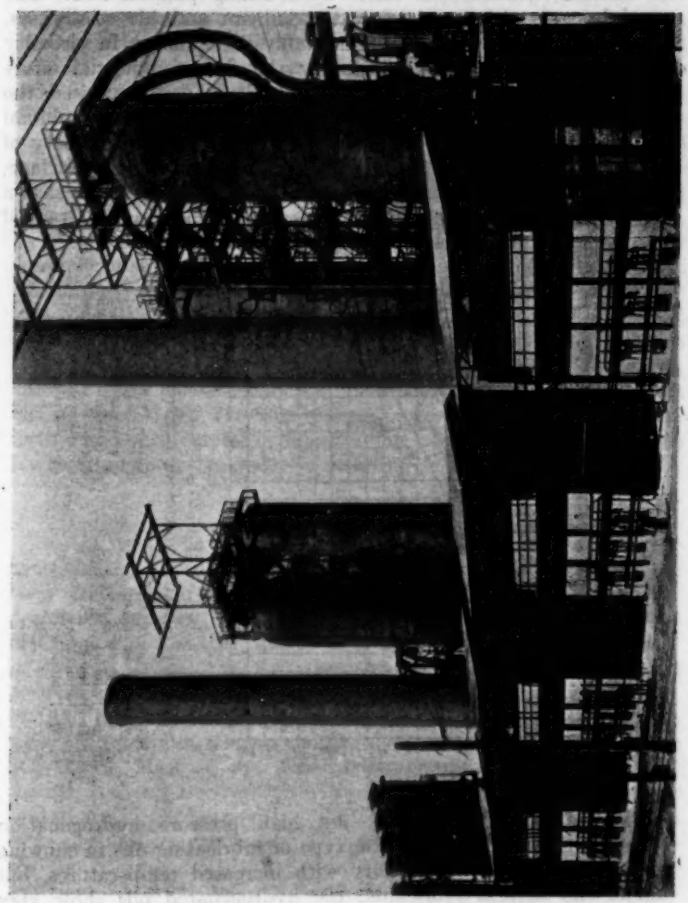

Fig. 1.

lubricating distillate, viscosity 433 seconds Saybolt U. at 100° F., having a pour test above 30° F. to a pour test, after adding 1 per cent. of the inhibitor, of −5° F. The inhibitor is known to the industry by the name "Paraflow."

Another outstanding development of interest has been the production on a commercial scale of synthetic lubricating oils made by the polymerisation by the action of aluminium chloride, on cracked hydrocarbons made by cracking paraffin wax. The new lubricants, developed by F. W. Sullivan and his co-workers, are free from wax and show remarkably little change in viscosity with rising temperatures. Probably the first commercial effort along this line was made by Brownlee,[13] who polymerised the light fractions of cracked gasoline by aluminium chloride. Sullivan and his associates studied the characteristics of a wide variety of polymers made from a series of olefins beginning with ethylene, and find that the best temperature-viscosity qualities are shown by the polymers of long chain olefins such as cetene and cracked paraffin wax. Their results are in part summarised in Fig. 2.

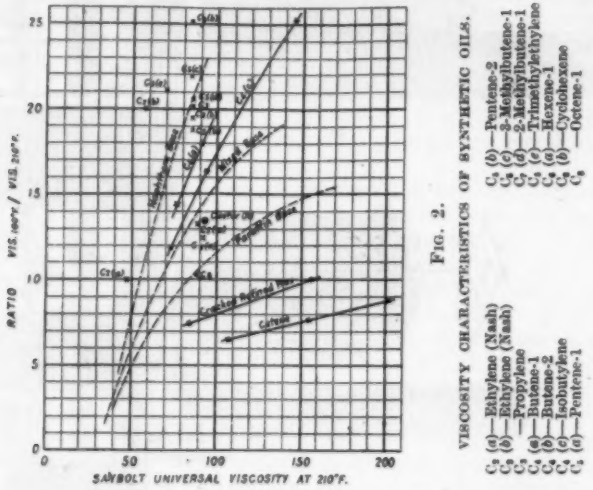

FIG. 2.—VISCOSITY CHARACTERISTICS OF SYNTHETIC OILS.

The lubricating oils made by high pressure hydrogenation resemble the best light paraffin type of lubricating oils in showing minimum decrease of viscosity with increased temperatures, but unlike the natural lubricants, the hydrogenated oils show very low carbon deposits. As stated by Haslam and Bauer (loc. cit.): "Paraffinic lubricants as commercially produced give greater and more objectionable carbon deposit than do naphthenic lubricants,

[13] U.S.P. 1,309,432; U.S.P. 1,374,277.

while naphthenic lubricants usually give higher consumption and have characteristically a much greater change of viscosity with a change of temperature." It will be noted that, confounding Nature, hydrogenation gives both lubricants resembling the best paraffinic types and also gasoline of very high anti-knock value. Haslam and Bauer give the results of the use of hydrogenated lubricating oil in White and Mack motor trucks in comparison with commercial lubricants of comparable viscosity made from different types of crudes. The results leave no doubt as to the excellent character of lubricants made by hydrogenation. The original paper should be consulted for details.

Another recent development which has already been adopted in refinery practice is the solvent extraction of lubricating oils, by which process lubricating oils, of the Mid-Continent type for example, may be separated into two oils, one resembling the best paraffinic type of lubricant and the other the extreme naphthenic type of oil. Ferris, Birkhimer and Henderson[14] have published the results of an extensive research in this field. While the idea is not exactly new, solvents such as liquid sulphur dioxide, acetone, aniline, ethyl acetate, phenol, nitrobenzole and other solvents having been tried for this purpose, Ferris and his co-workers have made very careful comparisons of a large number of solvents for their comparative value in effecting such a separation.

Acid Recovery.

Recent years have brought a series of improvements in the concentration of sulphuric acid, but a radical new departure has been developed in the past year which is peculiarly suited to the petroleum industry. The new method consists in the *regeneration* of the acid rather than its recovery by concentration. The undiluted acid sludge is heated to about 350° F., and the acid thus decomposed by the tar, sulphonic acids, etc., contained therein, to SO_2, water and CO_2. It is essential that the sludge contain sufficient organic matter to completely decompose the acid without SO_3 fume. Most of the water is condensed and removed, and the SO_2 is then passed with air through a catalytic plant to produce acid of any desired strength. The first commercial size installation is in operation, regenerating 50 tons of acid per day. The cost per ton of regenerated acid, exclusive of royalties, is said to be less than $3.00 per ton. A further advantage of the new process is that 92 per cent. of the original acid is recovered, as against an average of about 80 per cent. in the usual refinery practice of recovery by reconcentration.

[14] Ferris, Birkhimer and Henderson, *Ind. Eng. Chem.*, 1931, **23**, 753.

General Considerations.

The present general depression, combined with the demoralised condition of the oil industry resulting from conditions within the industry—*i.e.*, over-production of crude, great competition and over-capacity of refineries—has come just after most refiners had expended large sums for modernising their equipment. However, some authorities have sounded a note of warning that the over-production which has harassed the industry since the opening up of the great Seminole pool several years ago, is not a chronic condition. Indeed, according to Mr. Wallace Pratt,[15] an authority on oil geology in the southwest, we may look for a great change in this respect very soon. Mr. Pratt's analysis, if borne out in the near future, has such a direct bearing on the refining industry, that his summary is quoted as follows :—

"An all time record for discoveries of major pools was made four years ago. For the past three years barely enough major pools have been found to insure an adequate volume of oil. Our present reserve of ten billion barrels will last but ten years if our present requirements do not increase. As the entire reserve cannot be made available in ten years, geologists must find at least a billion barrels of oil per year to meet the certain demand for oil. This has not been done so far in 1931.

"Consider one further factor, please, in connection with the problem of oil finding. In order to find and produce the 23 billion barrels of oil involved in the accomplishment of the producing industry during the last 14 years, there have been or will be drilled nearly 400,000 wells. To find and produce the volume of crude oil required by this nation each year, we must drill on the average, basing our calculation on this record, which we are proud to display, some 20,000 wells. Our drilling record for 1930 is far below this average, and for 1931, so far, it is far lower still. One thing is certain, we can not find oil if we do not drill the wells. Our requirements for oil, on this basis, demand that we spend each year for drilling some 500 million dollars; that we explore and condemn by drilling some 3 million acres of prospective oil land to a depth exceeding on the average 3000 ft.; that we explore and prove for production each year some 50,000 acres of oil land. To do this well, we must keep our ratio of dry holes down to one in four, yet we are drilling one dry hole out of each three wells a great deal of the time and over much of our hunting grounds.

"In spite of over-production, new supply is actually lagging at the moment."

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[15] Wallace Pratt, *Oil and Gas J.*, 16.7.31, **30** (9), 19.

Refining in Asia.

By C. E. Spearing, M.A., F.I.C., M.I.Chem.E. (Member).

The flooding of Asiatic markets with oil at below cost, consequent on over-production in the U.S.A., combined with world-wide depression in industry, has, of course, affected their outlook for the immediate future, but as this commenced early in 1931 it had little effect on the expansion programme of the major companies operating in the East, several of which were either in process of reconstruction or else were committed to large schemes of expansion.

In point of fact, those companies which had considerable modernisation schemes in hand have been able to benefit from the more economical operation of the new units installed, and when forced to reduce throughput could shut down a proportion of their less modern equipment, which, though comparatively expensive to operate would certainly have been used in more normal times.

In general, progress in all refineries has followed normal lines. Increasing demand for anti-knock gasolines has led to the more general adoption of cracking equipment, a noteworthy example being at the Abadan refinery of the Anglo-Persian Oil Co., where four Cross-Kellogg combination cracking and viscosity breaking units of a total daily input capacity of 40,000 barrels have recently been installed.

At the Syriam refinery at Rangoon of the Burmah Oil Co., an additional Dubbs cracking plant has been installed, and successful runs have been carried out on the " alternating " reaction chamber system with a view to prolonging periods on stream.

Similarly, at Digboi, Upper Assam, the Assam Oil Co. (controlled by the Burmah Oil Co.) have also erected a complete double unit Dubbs cracking plant.

The cracking of kerosine distillates is being increasingly adopted for the production of benzine with a high anti-knock value with high percentage yield of spirit, while there is a definite trend towards the improvement of the fluidity of straight fuel oils at low temperatures, by subjecting them to mild cracking conditions.

The adoption of pipestills and bubble columns for crude distillation is now universal, and during the past year or so several units have been installed of 25,000 to 30,000 barrels daily capacity, while still larger units are stated to be under consideration.

At Syriam refinery, Rangoon, a large Foster Wheeler atmospheric and vacuum distillation plant was recently completed and placed in service.

With the widespread adoption of pipestill equipment it has been found necessary to pay particular attention to corrosion problems caused by small traces of acidic bodies, and in the Abadan refinery in particular, processing 4 million gallons a day, a novel method of alkali injection has been perfected, and has succeeded in eradicating completely a source of trouble, which at one time caused considerable embarrassment.

Far more attention than previously is now given to fuel economy and economies in labour, and to this end the adoption of automatic control equipment is gaining favour.

Gas recovery, both in the oilfields and in the refineries, is being more carefully watched than before, and absorption plants are, under certain conditions, replacing compression plants; examples of this can be found on the Yenangyoung and Singu oilfields in Burmah.

Floating roofs for crude and light oil storage are widely used, tests under service conditions having shown very clearly that this type of storage is more satisfactory than alternative methods of using insulated tankage, or combined storage and vapour recovery systems. Tests in Persia under summer conditions, where there is a considerable variation between day and night temperatures, indicate that tanks with floating roofs, and with uninsulated sides, show lower evaporation losses than similar tanks which have insulated sides, due to the higher heat conductivity of the metal coming into play at night when the air temperature drops and resulting in a lower daily average temperature.

One company, having upwards of 150 million gallons of crude storage has successfully adopted a scheme for reducing storage losses, whereby a small percentage cut is topped from the crude entering from the pipe-line, using a combination of steam preheating and vacuum flashing. The partially topped crude is then stored, while the overhead is separately stabilised and can be stored separately. A further advantage of this method is that gasoline recovered in the oilfields can be injected into the crude and piped down with it to the refinery, where it is recovered before the crude passes to the storage, with the consequent saving in capital cost of a separate gasoline line, storage facilities and pumps, etc. A very wild gasoline can thus be injected, allowing the excess of light constituents charged in with the crude to be recovered for fuel purposes in the refinery.

Due to the unique structure of the oil reservoir in their field at Masjid-i-Sulaiman, and also due to their having sole control of production, the Anglo-Persian Oil Co. has adopted a novel scheme whereby they have erected two large topping plants on their oilfields 150 miles from their Abadan refinery. These units

operate in conjunction with the refinery, and enable an economic balance to be maintained between their straight run and cracked products in line with fluctuating market requirements, eliminating the necessity for holding large stocks of oil at the refinery. In brief, the method used is to operate these units for the particular product required, pumping the unwanted material back into certain selected wells, where if it is fuel oil it acts the part of an absorption unit for gasoline recovery in the gas dome, and this returned oil is, as far as can at present be determined, available for eventual recovery as a synthetic crude, or if it is a distillate it serves the same selective purpose on the crude remaining in the limestone reservoir, which oil normally is irrecoverable.

It is stated that tests taken over a long period indicate that the wells which have received residue oil produce crude when reflowed, showing that very great enrichment has taken place.

A general improvement of kerosine for illuminating purposes is apparent, inasmuch as several installations of Edeleanu plants in Persia and Burmah have been completed. The aromatic extracts from the kerosine are being widely used for the production of power kerosines, and the lighter ends for the purpose of improving the knock-rating of straight run benzines.

The Burmah Oil Co. and the Anglo-Persian Oil Co. still make considerable use of bauxite for final polishing treatments of their products, and also use it as a dehydrating agent in preference to other more expensive reagents. Whereas the more conventional method of recovery is steam extraction, followed by roasting in rotary kilns, the Burmah Oil Co. report considerable success with recovery in situ, by the use of highly superheated steam. They claim this method to give equally satisfactory results at a low cost, and to effect considerable savings in the bauxite due to the elimination of handling losses. Owing, however, to the necessity of providing dry air for the oxidation of the impurities removed from the oil under treatment, and for the cooling of the material after high temperature steaming, it is necessary to have large refrigerating equipment, but where large scale paraffin wax extraction and lubricating oil manufacture are carried out, this is easily provided. It is considered that, but for the need for this supply of dry air, for which refrigeration to remove the moisture to the required low limits appears to be the only practicable method, the adoption of the in situ process of bauxite recovery would become more generally used.

Stream-line filters have been introduced, with very successful results, by the Burmah Oil Co. at their Syriam Refinery for separating minute quantities of clays during the final finishing process for lubricating oils.

This company has now adopted the Alanmor Stove in its refineries for the sweating of all the paraffin wax produced. These stoves were fully described in the paper read before the Institution in November, 1931, and it is stated that continued large scale operation fully bears out the claims originally made for them.

In the A.P.O.C. Refineries, in particular, great use is made of calcium hypochlorite for the sweetening of light products—the process is cleaner than acid and causes far less waste of material than this process through the complete elimination of acid tars, and does not affect the more unsaturated compounds, with the result that anti-knock value is maintained.

So far, however, there are no definite indications that acid treatment can be wholly dispensed with for the refining of cracked spirits, but considerable work has been done in Persia on the reduction of the quantity of acid necessary by adoption of alternative methods, such as two-stage stabilisation of pressure distillate, in order that the lighter materials may be segregated, leaving the heavier ends only to be treated by acid. This ensures that re-running losses are reduced to a minimum.

During the year under review, a plant for the production of 30 tons oleum per day, using Vanadium Catalyst, has been erected in Abadan, together with acid recovery and concentration equipment.

While at the present time imported sulphur is used as the raw material, work is in progress towards the substitution of this by the controlled oxidation of waste fuel gases containing sulphuretted hydrogen.

Progress has been made with the scientific control of the sweetening of distillates with Doctor Solution, and in the case of the less volatile products, such as kerosine, it would appear that the oxidation of mercaptans and simultaneous recovery of the reagent by passing a slow stream of air through a suspension of lead sulphide in the distillate to be treated, offers considerable advantages over the use of Doctor Solution as such, particularly so as it allows of continuous operation and obviates the loss of litharge, which is unavoidable in the more conventional system of batch washing and separate recovery of the plumbite.

Refining in Europe.

By S. Pilat, Ph.D. (Member).

The European petroleum industry has progressed during the last year as shown by the construction of numerous refineries, particularly in countries which possess little or no production of crude oil. The necessity for creating specific manufacturing industries, the publication of tentative legislative measures, commercial considerations relating to the maximum consumption of products, and last but not least financial prospects, may have caused this new tendency of development. The construction of certain refineries in France, which may possibly attain a total capacity of about 4,000,000 tons per year, and of others on a smaller scale, in Belgium and Italy, are indicative of the tendency mentioned. Since there was hitherto only an insignificant petroleum industry in these countries, the tradition of internal development has had to give way to the commercial testing and application of foreign, chiefly American, plant. A typical example of this is shown by the construction of a complete refinery in Germany, a country which is industrially very highly-developed, by a well-known American firm.[1] On the other hand, it seems that further developments of refining are limited for the most part to construction and expansion in the countries which, like Poland and Rumania, possess their own oilfields and refineries since neither the financial position nor the production and market conditions allow the realisation of greater technical programmes. The few modern plants which are registered in these countries are in any case controlled by American interests. In spite of the unfavourable general conditions, very interesting and important advances have been made from many points of view and are described shortly in the following remarks.

The manufacture of gasoline from natural gas is effected to a great extent in Europe by the activated charcoal process, and the new developments of the "Lurgi" Gesellschaft für Wärmetechnik essential advantages from a technical and economic point of view. A plant which has been working for a few months handles about 30 cu. m. per minute of natural gas with about 30 per cent. of air admixture. It was built according to the Activated Charcoal Process of the Carbo-Union by the "Lurgi" Co.,

[1] *Petr. Z.*, 1931, **27**, 389.

and consists of four absorbers without the interior heating system which was usually included in the old processes. The absorption space is divided into two parts for the easier and quicker regeneration of the charcoal, and a considerably increased efficiency is produced thereby. Moreover, the ratio of the quantity of activated charcoal to the quantity of gasoline formed is increased, and amounts now to 1 : 1·3–1·4, *i.e.*, 1·3 to 1·4 tons of gasoline can be produced daily from 1 ton of carbon. The duration of the time of absorption amounts to 40 minutes, the evaporation of the gasoline, and the drying and cooling of the charcoal requires altogether about 40 minutes. It is of interest to note that the plant operates under a small excess pressure of approximately ½ atmosphere. (Fig. 1.)

Numerous interesting observations were made regarding the influence of temperature and pressure on the percentage yield and change in the properties of the gasoline. About 90 per cent. of the gasoline in Poland and in Rumania was produced in this way.

The application of natural gas freed from gasoline for other purposes than for heating—*e.g.*, pyrolysis—has not achieved the stage of commercial-technical treatment in spite of many interesting investigations. Of the latter perhaps those of F. Fischer may be quoted,[2] insofar as many improvements have been made when the process has been carried out at normal pressure and at very high temperatures of 1150–1160° C. About 9 per cent. of the methane is converted into liquid hydrocarbons, principally benzene (61·1 per cent. of the distillate of specific gravity 0·8724). In a process in which more than sufficient quantities of natural gas were available a development was considered in which the gas is passed over a Fischer apparatus after separating the gasoline, the benzine and homologues formed are separated by means of activated charcoal and the residual gas is heated or utilised for power purposes. The proof of this is shown by the analysis of the residual gas which, according to Fischer, consists principally of 15–60 per cent. H_2, 15–78 per cent., CH_4.

The investigation of various methods of chlorination of methane which is related to the utilisation of natural gas has, so far as European conditions are concerned, not yet been abandoned.

The problem of disposal of products, even under normal financial conditions, is such that the petroleum researches are often directed towards reconstruction or elaboration of existing distillation apparatus. An interesting example of the solution of such a problem is provided by the process of Galizische Karpathen A.-G.

[2] *Brenn-Chem.*, 1929, **10**, 291.

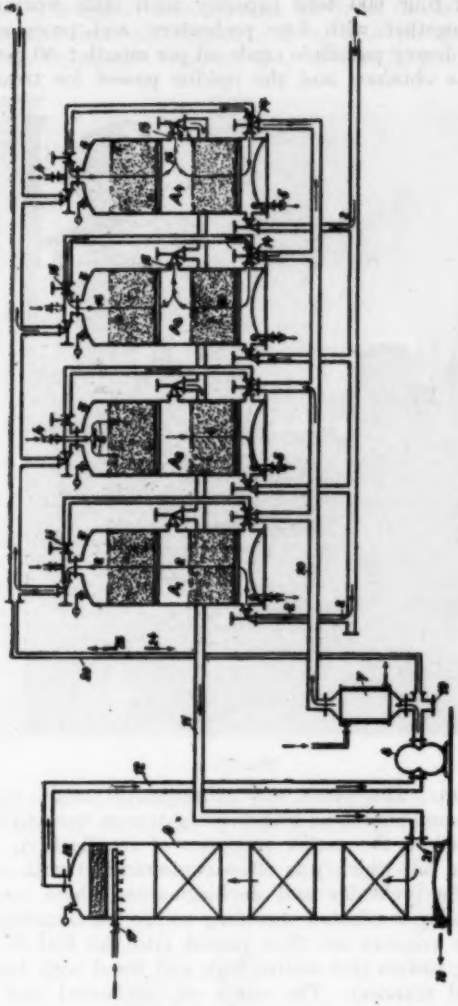

FIG. 1.

in Glinnik Marjampolski. (Figs. 2, 3.) This plant consisted originally of four 600 tons capacity shell stills working intermittently, together with four preheaters, and processed about 4500 tons of heavy paraffinic crude oil per month; 50 per cent. of distillate was obtained and the residue passed for treatment to

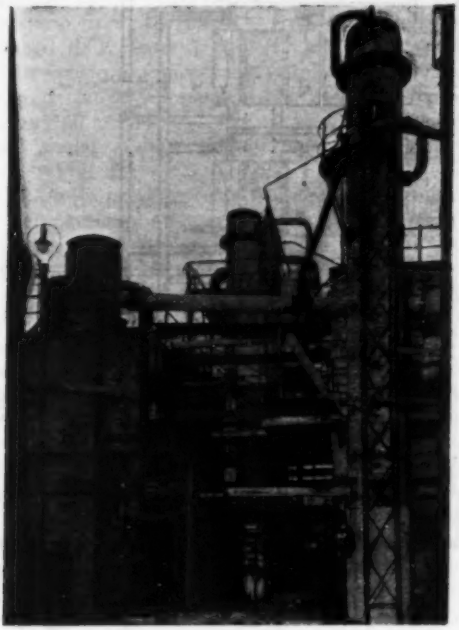

FIG. 2.

another plant. The plant was subsequently made continuous, and at the same time four fractionating towers were added which were excluded in the earlier processes of rectification. The unrefined crude oil, which was often contaminated with emulsions, passes to the preheater and dephlegmators where considerable or slight cooling is effected according to the fractionation requirements. The vapours are then passed into the first of the four fractionating towers (8·5 metres high and fitted with bubble caps in the usual manner). The crude oil, preheated and partially deprived of its benzine, flows to the tower into contacts with hot vapours introduced counter-current from the first still into the lower part of the tower. Here a partial condensation of heavy

portions and an evaporation of lighter constituents takes place. The crude oil is raised with a steam lift from the bottom of the tower into the first still, thence it flows into the second tower, in which the distillation vapours flow counter-current and so on.

FIG. 3.

The fourth tower is an exception since it acts as a dephlegmator. The difference in the effect of this process is illustrated in the following table :—

	Tower I.		Light unrefined benzine before reconstruction of the plant.
Specific gravity ..	0·740		0·733
Initial boiling point ..	80° C.		45° C.
	90° C.	29%	
	100° C.	58%	43·0
	110° C.	77%	
	120° C.	88%	
	130° C.	93%	
	140° C.	96%	84·0
			97·0
Final boiling point ..	148° C.		220° C.

The effect was quite significant in the heavy fractions.

Tower IV.

	Distillate.		Tower residue.		Corresponding fraction before reconstruction of the plant.
	0·846		0·868		0·846
	—8° C.		22° C.		0° C.
	236° C.		302° C.		220° C.
	300° C.	60%	—		300° C.—58%
Final boiling point ..	336° C.		360° C.	51%	360° C.—94%

The tower residue is a good pressable paraffin oil distillate which can be handled immediately in the paraffin plant. Fuel consumption amounts to about 5 per cent.; approximately 16 kgm./100 kgm. of crude oil being necessary for the boiler, pumps and steam lifts. The output of the plant was increased by more than one and a-half times that obtained previously with a corresponding reduction of half the labour costs. Regarding the plant previously mentioned which distils the crude oil residue to coke, it should be noted that the use of preheaters and dephlegmators in the primary distillation of the crude oil causes a reduction in the ash content of the coke to two-thirds of the previous value. It should be mentioned that the earlier results obtained do not differ essentially from those of first-class new plants, as is instanced by a comparison of the figures quoted with those given in the literature[3] for a well-known distillation plant constructed according to Allan's process (Steaua Romana). The comparison is, however, limited, due to the difference in the crude material. In Allan's process, the crude oil is conducted continuously to a still containing a flash tube surrounded by a casing with a vapour-injector at the lowest point. In this way a rapid circulation of the crude oil is effected round the flash tube, and not only results in a much better heat transfer but also obviates the hitherto usual coke formation in the interior of the flash tube.

Of new distillation plants, in most cases pipe-stills with fractionating towers, the latest is a Foster-Wheeler unit erected in Lemberg, Poland, which can be utilised, especially on the small scale, for crude oil distillation at atmospheric pressure and also for lubricating oil distillation under low pressures of about 25 mm.

The Brünn Königsfelder Maschinenfabrik has lately erected some pipe-still plants, one of which is in the Fanto works in Pardubitz, Chechoslovakia. These plants are fitted with two fractionating towers, the steam-heated stripping sections being attached from outside the effective fractionating columns. Russian paraffinic crude oil is distilled at a transfer temperature of 430° C. to an asphaltic residue representing 7·5 per cent. of the charge. Seven

[3] *Petr. Z.*, 1931, **27**, 687.

distillate fractions and an asphalt of softening point 50–55° C. are obtained, the latter being practically free from constituents insoluble in benzine.

With regard to the distillation of lubricating oils, the well-known firm, F. Heckmann, Berlin, has introduced a new device in their vacuum distillation apparatus. This process, unlike other pipe-still plants, is operated with fractional distillation instead of fractional condensation. Heating is effected indirectly by a circulation of hot water and steam, which enables the temperature of 450° C. to be reached, and is controlled so that the temperature of the heating medium is the same as the boiling point of the oils. The apparatus can be operated continuously at 0·5 mm. pressure, which appears to be particularly advantageous in view of the well-known form of the vapour-pressure curve of the oil.

The development of cracking process is limited generally to the construction of American plant, such as Cross, Dubbs, Holmes-Manley and Jenkins. Apart from the hydrogenation processes of the I. G. Farbenindustrie, European plants are very rarely mentioned. Of these, two were set into operation by the Carbural Plant, one in France and one in Poland. With these processes the decomposition only takes place in the pipe system, only the heat exchange tubes and the furnace coils being under pressure. The tube-heater system discharges through an expansion valve into a tower, and the oil is cooled below cracking temperature by means of incoming cold oil. In this way the cracking reaction ceases, and the heavy portion, the residue, separates from the benzine vapours. The heavier fractions of the fresh oil which have mixed with the residue are probably vaporised at this point. Further details of the apparatus are a heat exchange device and a dephlegmator, in which a part of the pressure distillate condenses and mixes with the fresh oil, the latter being passed through a hot oil-pump into the cracking tubes. Data of the Polish process, which has a throughput of about 25 tons per day, are given below :—

Temperature of the furnace		750° C.
Temperature of the cracking space		450–460° C.
Pressure		60–70 atmospheres
	Preheater Tube.	Heating tube.
Length	571 metres ..	442 metres
Diameter	59/77 mm. ..	35/54 mm.
Heating surface ..	120 sq. metres ..	75 sq. metres
Velocity of flow ..	0·72 metres/second ..	2·0 metres/second
Capacity of tube ..	1557 litres ..	430 litres

Gas oil (specific gravity 0·864 and 41 per cent. distillate to 300° C.) was cracked under a pressure of 65 atmospheres yielding 50–54 per cent. of distillate (specific gravity ·760) and 31·33 per cent. of residue (specific gravity 1·065). The distillate gave on redistillation

86 per cent. of benzene (specific gravity ·750) to 200° C. or 46·5 per cent. by weight on the cracking stock. In view of the fact that as the tubes are arranged in spiral form the plant need not be expensive, and also that even a small plant will produce 20 tons—*i.e.*, about 150 barrels per day—of spirit, it appears to be more suitable for small scale work than large cracking installations which can rarely be operated profitably.

Another process for the cracking of heavy hydrocarbons is that of Blümmer, which was described briefly by Wischin.[4] It operates with two furnaces, and in such a manner that the charge is brought to cracking temperature in the first and cracking takes place in the second (the superheater) on further addition of heat. This second super-heating furnace consists of short vertical double-walled tubes. It is not known whether the process is of any technical importance. The original Blümmer process in which molten metal is utilised as the heating means is not the same as that described above.

A process for the direct cracking of shale oil was introduced by the firm, F. Heckmann, Berlin, and utilised in Estonia.[5] Nothing is known of the construction of the apparatus, but the yields obtained from heavy crude shale oil are shown by the following :—

Cracked benzine	24·6%
Furnace oil	15·0%
Residue	55·6%
Loss—gas	4·8%

The small yield of gas is worthy of note.

Certain advances have been made in the manufacture of paraffin, especially in those countries which, like Poland, endeavour to obtain the maximum yield of paraffin wax from crude oil. Since the introduction of high vacuum distillation, it is necessary to remove the paraffin from the heavy and very viscous oils without subsequent redistillations. Sharples centrifuging and the use of inorganic filter-aids are of great importance.

The sweating of paraffin has recently been improved by means of the Alanmor sweating oven, which gives an accurate separation of the components and a decrease in the time of operation. A description of the process, together with the subsequent discussion, is given in this journal.[6]

A special branch of the application of paraffin concerns those processes which have so far no technical value, *e.g.*, the production of oxidation products, acids and alcohols. An ever-increasing

[4] *Petr. Z.*, 1931, **27**, 551.
[5] *Petr. Z.*, 1931, **27**, 492.
[6] *J.I.P.T.*, 1931, **17**, 657.

number of patents[7] relating to these processes signify the possibility of future development in this direction.

The production of asphalt for road-building is closely connected with distillation problems and the occurrence of paraffin in petroleum. The question of greatest interest is whether and to what extent paraffinic asphalt is suitable for road-building. So far as present researches extend,[8] it is assumed that even highly-paraffinic asphalts can yield with suitable treatment suitable road-building material as shown by the following results :—

American normal standards	Asphalt with 7% paraffin
Specific gravity 1·0–1·06	1·0–1·06
Flash point 177°C.	above 200° C.
Softening point 35–55° C.	35–40° C.
Penetration at 25° C. 80–130	80–150
Loss in weight after 5 hr., max. 3%	1%
Penetration after heating, min. 50%	above 60%
Ductility (25° C.), min. 40 cms.	50–80 cms.
Solubility in CS_2, min. 95%	above 97%

It must be mentioned that although much work has been carried out on the question of the form of the paraffin in the asphalt,[9] the results are still not considered conclusive.

It is evident from numerous articles dealing with the application of alcohol as a motor fuel that alcohol has become of increasing importance in those countries whose agriculture is dependent on the production of spirit. An account of detailed work on this subject from a physico-chemical point of view was published by Swietoslawski and his co-workers.[10]

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[7] I. G. Farbenind. A.-G., E.P. 327,707 ; E.P. 353,047 ; U.S.P. 1,762,688 ; D.R.P. 500,913 ; F.P. 680,351 ; F.P. 680,620.

[8] *Petr. Z.*, 1930, **26**, 685.

[9] *Asphalt und Teer*, 1931, p. 669.

[10] *Przemysl Chem.*, 1930, p. 337, etc.

The Cracking Art in 1930-1931.*

By Gustav Egloff, Ph.D., M.A., M.Am.Inst.Chem.E., M.Am. Chem.Soc. (Member), Badona L. Levinson and Margaret Herrman.

I. Introduction.

The art of cracking has advanced since the survey[1] made for 1928-29, accelerating during 1930 and 1931 in efficiency and flexibility as well as expanding greatly in volume. Cracked gasoline production in the United States increased from 394,000 barrels daily in 1929 to 432,000 barrels in 1930, and, again in 1931, to 488,000 barrels. On the other hand, straight-run gasoline and natural gasoline have shown decreased production. The output of the three gasolines is illustrated in Fig. 1.[2]

The use of the cracking process to produce gasoline has been stimulated, not only by the fact that it allows a greater yield of gasoline from crude oil, but particularly by the increasing demand for gasolines of high anti-knock value.

Increase in the required octane number of commercial gasoline has become so marked and the cracking process has become so flexible that refiners are cracking not alone naphtha, kerosine, gas oil or fuel oil, but crude oil in its entirety; and they are also cracking straight-run gasoline to increase its anti-knock value.

An interesting census of cracking plants is presented by Chatfield[3] showing the increase in daily capacity of cracking plants in the United States from 1,288,000 barrels in 1928 to 1,950,781 barrels in 1931.

Expansion of the cracking art has been marked in other countries besides the United States. The U.S. Bureau of Foreign and Domestic Commerce[4] reports 63 Dubbs cracking units, 32 Cross cracking units and 12 Jenkins cracking units in operation or under construction in foreign countries.

Glenn[5] indicates that almost every continent is now equipped with modern cracking plants, and Truesdell[6] discusses the importance of cracking as the answer especially to Europe's refining

* This report covers publications from November 1st, 1929, to November 1st, 1931.

[1] Egloff, Lowry and Schaad, *J.I.P.T.*, 1930, **16**, 183.

[2] Willson, *Oil and Gas J.*, 17.7.30, **29** (9), 39; also U.S. Bureau Mines Monthly Petroleum Statement, No. P87, November, 1931.

[3] *Nat. Petr. News*, 25.11.31, **23** (47), 25.

[4] *Trade Information Bull.* 723, 1930, p. 41–42.

[5] *Petr. Eng.*, Feb., 1931, **2** (5), 78.

[6] *Oil and Gas J.*, 25.9.30, **29** (19), 154.

problem. The development of the oil industry in Italy, where no oil is produced, is being based, according to Egloff[7], upon the building of cracking plants, while Peru, a large producing country, is reported by Chappius[8] to have four 2400-barrel cracking units. Russia's plans for 1930-31, according to Shipman[9], call for over 100 cracking plants, the majority of her refineries producing gasoline by cracking.

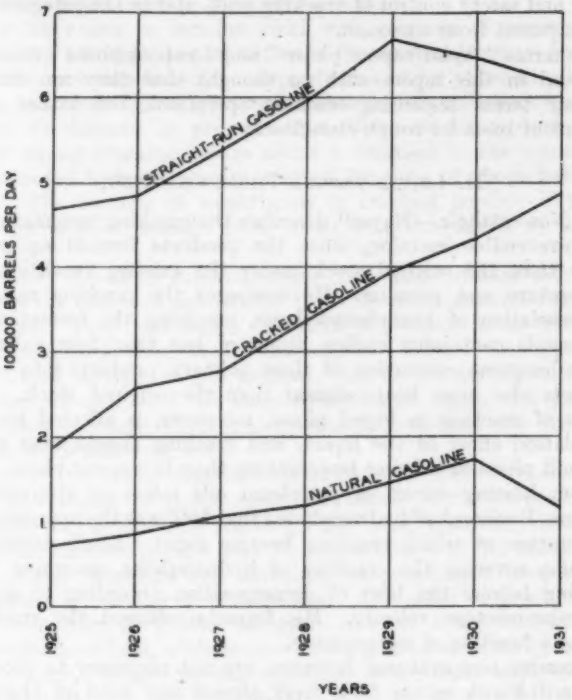

FIG. 1.

GASOLINE PRODUCTION IN THE U.S.A.

Reid[10] states that the knowledge of chemistry applied to cracking in the petroleum industry has increased gasoline recovery by 16·4 per cent.

[7] *Refiner*, Oct., 1930, **9** (10), 75.
[8] *Petr. World and Oil Age*, April, 1931, p. 41.
[9] *Refiner*, Oct., 1930, **9** (10), 78.
[10] *Petr. Marketer*, 1930, **14** (11), 169.

But gasoline is not the only valuable product of the cracking process, for it also yields fuel oil residues, road oils, asphalt, gas or coke. Further, much interesting work has been done in the development of useful by-products of cracking such as alcohols and lubricating oils.

Continued advance has been made in 1931 in the development of more efficient equipment for the mechanical operation, automatic and safety control of cracking units and in the safeguarding of equipment from corrosion.

The terms " liquid-vapour phase " and " vapour phase " cracking are used in this report with no thought that they are strictly accurate terms describing cracking operations, but rather as a convenient basis for rough classification.

II. Liquid-Vapour Phase Cracking.

(*a*) *Non-catalytic.*—Mayer[11] describes the cracking mechanism as a non-reversible reaction, since the products formed are more stable than the original stock under the existing conditions of temperature and pressure. He compares the cracking reaction to dissociation of hexaphenylethane, assuming the formation of compounds containing carbon atoms of less than four valencies and subsequent conversion of these primary products into other products also more heat-resistant than the original stock. The extent of cracking in liquid phase, moreover, is affected by the dissociation effect of the liquid, and cracking should take place in liquid phase at a lower temperature than in vapour phase.

From heating curves of petroleum oils taken at atmospheric pressure, Ryonosuke[12] had concluded that 300° was the approximate temperature at which cracking became rapid. Kiss[13] developed formulas covering the cracking of hydrocarbons, assuming that cracking follows the laws of decomposition according to monomolecular-reaction velocity. His formulas showed the cracking rate as a function of temperature.

Excessive temperatures, however, are not necessary to produce high anti-knock motor fuels from almost any kind of charging stock according to data presented by Egloff and Nelson.[14] Under pressures of 210 to 350 lb. per sq. in. at temperatures of 925 to 967° F., they produced gasoline yields of 53 to 78 per cent. of the charge, the motor fuel having knock-ratings of 54 to 71 per cent. benzole equivalent or octane numbers of 68 to 88.

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[11] *Petr. Z.*, 1930, **26**, 1248.
[12] *J.S.C.I., Japan*, 1929, **32**, 152 ; Chem. Abs., 1929, **23**, 5035.
[13] *Ind. Eng. Chem.*, 1930, **22**, 10.
[14] *Oil and Gas J.*, 13.11.30, **29** (26), 56.

The influence of high pressures on the yields and properties of cracked gasoline was studied by Sachanen and Tilicheev[15] who worked with Russian mazouts and gas oils. They conclude that :—

"1. In the initial stages of cracking (up to 10 per cent. benzine yield) the increase of pressure has very little effect.

"2. Rather strong cracking (25 to 30 per cent. benzine yield with a pressure increase of 10 to 40 atmospheres) causes a decrease of about 3 per cent. in the benzine yield.

"3. Decreases in benzine yield with increase of pressure are caused by a further decomposition of the cracked benzines through partial conversion into gaseous products and by polymerisation of part of the unsaturated hydrocarbons into higher-boiling compounds.

"4. An increase in pressure from 10 to 40 atmospheres with fairly strong cracking brings about a decrease in the content of unsaturated hydrocarbons in cracked benzines of about half.

"5. The content of naphthenes in cracked benzine increases with increase of pressure from 10 to 40 atmospheres, by 3 to 4 per cent."

Earlier, the same experimenters[16] had made similar investigations of the effects of pressures of 10 to 100 atmospheres on cracked gasolines. They had found the yield of gasoline lower at 20 to 80 atmospheres than at 10 atmospheres. When the apparatus was cooled as soon as the pressure rose to 100 atmospheres, the vapours released, and the temperature raised again, the yield of gasoline was nearly constant at increasing pressures, only dropping a little at 40 atmospheres.

Hugel[17] reported experimental cracking of pure hydrocarbons with the object of determining the effects of temperature and pressure on the cracking reaction. He found that the velocity of reaction increased greatly with the temperature, as did the proportion of gas. Pressure also intensified the cracking action, and so permitted a lowering of temperature. The effect of pressure was only secondary to render the vapours more dense and increase transmission of heat, while most secondary reactions were intensified by pressure. Hugel reports especially work done with tetralin and decalin.

The correlative effects of temperature, time and pressure upon the results of cracking petroleum hydrocarbons are emphasised by Frolich.[18] He, too, notes marked decomposition at 300° C., and describes the rate of cracking as a function of temperature. Simple hydrocarbons, with the exception of acetylene, decrease in

[15] *Oil and Gas J.*, 19.12.29, **28** (31), 48.
[16] *Oil and Gas J.*, 28.11.29, **28** (28), 46.
[17] World Power Conference, 1930; *J.I.P.T.*, 1930, **16**, 390A.
[18] *Chem. and Met. Eng.*, 1931, **38**, 343.

stability with increased temperature. The complete cracking process, according to Frolich, "is a sequence of decomposition and polymerisation reactions, the character of the final products being determined largely by the nature of the hydrocarbons present in the original cracking stock, by the temperature and pressure of operation, as well as by the time of exposure to cracking conditions . . . the rate of polymerisation increases with temperature, but apparently much less rapidly than the rate of simple molecular breakdown. If the temperature is high and the pressure low there is a tendency for polymerisation to take place with simultaneous liberation of hydrogen. By increasing the pressure, however, the hydrogen evolution is counteracted."

McKee and Szayna[19] attempted to illustrate the mechanism of conversion by cracking at temperatures higher than critical temperatures. They used gasolines and pure hydrocarbons as charging stock, subjected these to temperatures of 405-450° C., and determined critical temperatures before and after cracking for several periods. Change of critical temperature indicated that for paraffin hydrocarbons and straight-run gasolines the cracking process is a linear function. Ordinary gasolines crack at one rate, saturated hydrocarbons more rapidly, and unsaturated hydrocarbons still more rapidly.

An interesting contribution to cracking is made by Henri,[20] based on a spectroscopic method for determining the energy necessary to break carbon-carbon and carbon-hydrogen bonds in various types of compounds. Investigation of spectra enables accurate measurement of the dimensions, etc., of molecules, while recent progress permits the calculation of the "energy of activation"—*i.e.*, the energy necessary to produce a certain reaction. Similar methods allow determination of required energy for dissociation of molecules. These methods are based on the calculation, from the spectra, of the distance between atoms in a molecule as compared with those distances for other molecules. Thermochemical methods are approximate, whereas the use of absorption spectra offers a possibility for accurate determination and control of energies for given reactions.

Singer[21] reported variations of temperature, pressure and time in the cracking of Russian mazouts and crude oils to form: (1) better quality fuel oil; (2) gasoline and fuel oil; and (3) gasoline and coke. He concluded that:—

"The velocity of the reaction is doubled for every rise in temperature of 10° C.

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[19] *Ind. Eng. Chem.*, 1930, **22**, 953.
[20] *Rev. Pétrolifère*, 1931 (411), 202.
[21] *Petr. Z.*, 1929, **25**, 893; ibid., 1930, **26**, 484.

"The velocity of the formation of coke depends on the chemical composition of the cracked petroleum products. Paraffin products yield less coke than paraffin-free or asphaltic products. Kerosine yields practically no coke; solar and spindle oils yield very little; machine and cylinder oils yield considerable quantities of coke, and tars increase the coke formation to a great extent.

"Increase of pressure causes a decrease in the content of unsaturated hydrocarbons. . . .

"The details of a cracking process are not determined so much by the yields of cracked benzines, which are the same for a given temperature and cracking time with heavy crude oils and mazout, but are more dependent on the yields of coke which vary for different products."

The development of the flexibility of the cracking process and control of operating conditions has been attended by the expansion of the number of charging stocks. Stocks for cracking now include petroleum oils ranging from the heaviest distillation residues—*e.g.*, reduced crudes and residues from cracking—over the whole range of distillates—*e.g.*, gas oil, kerosine—to the lightest naphthas and gasoline. It has also been found economical, in some cases, to use the whole crude as the cracking stock to produce a yield of cracked gasoline comparable to the combined yields of straight-run gasoline and cracked gasoline from the topped crude.

Nelson and Egloff[22] report the cracking of crude oil from Joiner field in Texas to produce 71 per cent. of 70 octane number gasoline, whereas cracking the topped crude and blending the cracked and straight-run gasolines gave the same yield of a product having an octane number of only 66. Throughput capacity was estimated to be increased by 30 per cent. for an oil containing 35 to 40 per cent. of gasoline.

Burstin and Urman[23] report the cracking of Boryslaw crude oil in a "specially designed apparatus which permits the application of pressure up to 60 atmospheres."

Topped Ural crude oil was used as charging stock by Tilicheev,[24] to be cracked in the laboratory at 425° C. under 10 to 20 atmospheres. He obtained 10 per cent. of gasoline and 86 per cent. of residue, but the gasoline yield was increased to 22 per cent. by recycling the gas oil fraction. Greater gasoline yield was accompanied by coke formation.

Leach[25] reports a method for handling heavy reduced crude cracking stock in such a way that the heavy asphaltic ends of the

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[22] *Oil and Gas J.*, 2.7.31, **30** (9), 20.
[23] *Przemysł naftowy*, 1930, **5**, 545; *Chem. Abs.*, 1931, **25**, 5548.
[24] *Neft. Khoz.*, 1929, **17**, 82; *Chem. Abs.*, 1930, **24**, 1730.
[25] *Refiner*, Jan., 1930, **9** (1), 89.

charge are eliminated before reaching the cracking tubes. The raw feed is preheated to 749° F., and is commingled with the vapours from the cracking coil at 910° F. Light cracking occurs in the vaporiser and the asphaltic residue is dropped out. Maximum safe capacity is increased over 60 per cent. and length of runs from 10 to 60 days.

The cracking value of straight-run gas oil as compared with cycle gas oil was investigated by Sydnor and Patterson[26] by passing cycle gas oil through a small-scale cracking unit. With the same operating conditions, in successive passes through the apparatus, the yield of gasoline, based on the feed stock to each pass, decreases; ratio of fuel oil to gasoline increases; boiling range of the cycle gas oil is lowered, and the A.P.I. gravity for a given boiling range is lowered. It is concluded that the cracking value of cycle gas oil, in terms of the cracked products, decreases with successive passes through the apparatus.

Alberding and Keightly[27] indicate advantages, when economy permits, of using gas oil instead of residual cracking stock. Yields from the two charging stocks compared as follows, under a pressure of 227 lb. per square inch :—

	Pressure distillate.	Coke.
	%	%
Gas oil	72·5 ..	15·0
Residue	55·0 ..	30·0

The capacity of the plant was less per 24 hours with gas-oil charge, but the cycle was 120 hours as compared with a 48-hour cycle, with residue.

Paraffin-free and paraffinic gas oils were cracked at 650° C. with continuous recycling. The experimenters, Tarasov and Rudenko,[28] concluded that gas oil can be cracked repeatedly by removing the tarry products boiling above 320° C. and without influencing the formation of coke. Adding the heavy fractions from the previous cracking leads to an increase of aromatic hydrocarbons in the gasoline. The heavy residues after repeated cracking are also very high in aromatic hydrocarbons.

The same workers[29] have previously made similar runs, using as their charging stock kerosine which was heated to 600-610° C. in an iron tube. The gases obtained were highly unsaturated and amounted to 50 per cent. of the products. A total yield of 45 per cent. of gasoline was recorded, which increased in aromatic hydrocarbon content with each cracking operation.

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[26] *Ind. Eng. Chem.*, 1930, **22**, 1237.
[27] *Mon. Petr. Roumain*, 1931, **31**, 291; *J.I.P.T.*, 1931, **17**, 286A.
[28] *Neft. Khoz.*, 1931, **19**, 599; *Chem. Zentr.*, 1931, **102**, I 2826.
[29] *Neft. Khoz.*, 1929, **17**, 530; *Chem. Abs.*, 1930, **24**, 1731.

McConnell[30] reports cracking operations on even lighter stock for the purpose of making a product of good knock-rating from unsaleable crude naphtha. Naphtha from Mid-Continent crude was cracked at 925° F. under 1000 lb. pressure, yielding 82 per cent. of 400° F. end-point distillate of 70 octane number, which needed only washing with lye to produce finished gasoline.

A series of articles by Egloff, Nelson and Truesdell[31] presents data on the cracking of various charging stocks obtained from oil fields of the United States and other countries. Operating conditions for these tests included temperatures from about 850-950° F. under pressures of about 200-350 lb. per square inch. Yields of cracked gasoline from the various stocks and their knock-ratings are shown in the table :—

Charging stock.	Source.	Gasoline % of charge.	Octane number.
Crude oil	Refugio, Texas ..	59–61 ..	88–90
,, ,, ...	Joiner, Texas ..	71 ..	70
,, ,, ...	California	58–72 ..	—
,, ,, ...	Nienhagen, Germany	57 ..	74
,, ,, ...	Edessa, Germany ..	68 ..	73
Topped crude ..	Refugio, Texas ..	47–52 ..	75–79
,, ,, ..	Oklahoma City ..	57–63 ..	—
,, ,, ..	West Texas ..	40–62 ..	—
,, ,, ..	Pettus, Texas ..	73 ..	73
,, ,, ..	Kentucky	51–55 ..	75–77
,, ,, ..	California	65–80 ..	—
,, ,, ..	Joiner, Texas ..	51–62 ..	68–71
,, ,, ..	Van, Texas.. ..	38–61 ..	70–73
,, ,, ..	Michigan	62–63 ..	67–68
,, ,, ..	Peru..	47–53 ..	74
Fuel oil	Mid-Continent ..	58–60 ..	75–76
,, ,, ...	Venezuela	26–27 ..	76–78
Residuum	Joiner, Texas ..	79 ..	74
,, ...	Argentine	57·9 ..	—
Heavy residuum ..	Egypt	52–55 ..	—
Gas oil	Mid-Continent ..	64–58 ..	80
,, ,, ...	California	59 ..	78
Kerosine	California	86 ..	80
,, ...	Mid-Continent ..	72–74 ..	80–84
,, ...	West Texas ..	70–72 ..	74–89
,, ...	Pennsylvania ..	73–78 ..	74–79

Improvements incorporated in various cracking units have been described by different authors. Bender[32] and Naphthali[33] describe the salient points of the Carburol unit. Later, Bender[34] reports

[30] *Oil and Gas J.*, 7.5.31, **29** (50), 16.

[31] *Oil and Gas J.*, 16.1.30, **28** (35), 46 ; 6.11.30, **29** (25), 38 ; 12.2.31, **29** (39), 38 ; 19.2.31, **29** (40), 30 ; 5.3.31, **29** (42), 88 ; 2.4.31, **29** (46), 30 ; 16.4.31, **29** (48), 30, 140 ; 23.4.31, **29** (49), 30 ; 21.5.31, **30** (1), 40 ; 18.6.31, **30** (5), 22 ; 2.7.31, **30** (7), 16 ; 23.7.31, **30** (10), 22 ; 6.8.31, **30** (12), 22 ; 22.10.31, **30** (23) 22.

[32] *Petr. Z.*, 1929, **25**, 1187.

[33] *Brenn. Chem.*, 1930, **11**, 247.

[34] *Petr. Z.*, 1931, **27**, 53.

results from a Carburol plant in France where yields of 63 per cent. of gasoline, 19 per cent. heavy oil, 18 per cent. gas and loss, and no coke were obtained from a mixture of gas oil and kerosine. Operating conditions comprised temperatures of 490° C. under inlet and outlet pressures of 80-85 atmospheres and 40 atmospheres respectively.

The Donnelly cracking unit, according to Ziegenhain,[35] operates upon topped crude without producing coke, and employs no reaction chamber. Another installation, known as the Seelig, is described by Salmony-Karsten.[36]

The use of the Dubbs cracking process for processing kerosine distillates is reported by Henny and Alberding.[37] They quote yields of 61·8 to 68·2 per cent. of gasoline, producing a flashed residue to meet Bunker C fuel oil specifications. Willson[38] describes a Dubbs installation at Canton, Ohio, which corresponds in all points with much larger plants. Another small-scale Dubbs cracking unit is being operated at Langerbrugge, Belgium, according to Truesdell.[39] Nelson and Alberding[40] report the use of the Dubbs process in Pennsylvania refineries to produce gasoline of 74 octane number.

A cracking plant, developed to permit sufficient variation of temperature, time and pressure so that products of either liquid or vapour-phase type may be produced has been described by de Florez.[41] Primary cracking takes place in the heater and secondary cracking in the base of the expansion chamber. When operating at high temperatures and low pressures, primary cracking predominates and the products are of the type associated with vapour-phase operation. Gradual increase of pressure increases secondary cracking and the distillate resembles that obtained by liquid-phase operation, the change becoming marked at pressures of 50 to 60 lb. per square inch. The unit described has run for 600 to 700 stream hours at heater outlet temperatures of 1050° F.

In Russia the Vickers installation is being used to crack Surakhani mazout. Bespolov[42] describes the properties of the cracked products. The cracked gasoline, of low initial boiling point, has good anti-detonating qualities indicated by the presence of considerable amounts of aromatic and unsaturated hydrocarbons.

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[35] *Oil and Gas J.*, 27.2.30, **28** (41), 46.
[36] *Petr. Z.*, 1930, **26**, 1015.
[37] *Petr. Z.*, 1930, **26**, 960; *Petr. Times*, 1930, **24**, 189.
[38] *Oil and Gas J.*, 21.8.30, **29** (14), 46.
[39] *Ind. Eng. Chem.*, News Ed., 1930, **8**, 6.
[40] *Nat. Petr. News*, 1931, **23** (29), 42.
[41] *Oil and Gas J.*, 5.12.29, **28** (29), 132.
[42] *Azer. Neft. Khoz.*, 1929, (6–7) 79, (10) 57; ibid., 1930, (6) 99, (9) 104; *Chem. Abs.*, 1930, **24**, 952, 5143; ibid., 1931, **25**, 805.

The cracked kerosine is recommended as tractor fuel. Bespolov considers that temperature and pressure have more influence on the composition of the cracked gasoline than the recycling ratio. Bogoslovskii[43] and Bogoslovskii and Margulov[44] also describe the operation and cracked products of the Vickers unit as used on Surakhani mazout.

Margulov[45] and Kostrin[46] have published descriptions in Russia of the operation in America of the Cross and Winkler-Koch units respectively.

(*b*) *Catalytic.*—Cracking experiments on North Japanese petroleum oil have been reported by Oda[47] who found that, in the presence of catalysts, the amount of cracked oil decreased with corresponding increases of gas and coke. The catalysts tried included iron, nickel, aluminium, zinc, magnesium, silicon oxides, and "pieces of iron and bleaching earths." The best catalyst, silicon dioxide, gave 73 per cent. of cracked oil.

Tichy[48] cracked paraffin oils with catalysts to obtain products containing aromatic hydrocarbons not contained in the original oil and the usual unsaturated hydrocarbons. The cracking was carried out in an autoclave. Without catalysts 95·8 per cent. of oil, containing 30 per cent. of unsaturated and aromatic hydrocarbons, was obtained with 2 per cent. of gas in 155 minutes. Zinc chloride decreased the cracking time by 45 minutes, functioning as a dehydrogenator. Anhydrous aluminium chloride showed marked cracking with polymerisation, the gas yield being 3·7 per cent. and the oil containing 4 per cent. unsaturates and 24 per cent. aromatics. Nickel and cobalt chlorides acted similarly. Stannous oxide was very destructive, yielding an oil containing 17 per cent. aromatics and 15 per cent. unsaturates. Chromium, molybdenum and tungsten oxides acted similarly. An ionium mixture yielded an oil containing 18 per cent. of unsaturates and 22 per cent. of aromatics. The best catalysts were aluminium chloride, stannous oxide and ionium.

III. Vapour Phase Cracking.

Atmospheric pressure experiments on a representative Mid-Continent gas oil have been conducted by Geniesse and Reuter.[49] A large number of runs carried out between 430° C. and 700° C.

[43] *Azer. Neft. Khoz.*, 1929, (5) 56; *Chem. Abs.*, 1930, **24**, 3106.
[44] Repts. of Sci.-Tech. Council of Oil Ind., Session of Refinery Section in Baku, 1929, I. Cracking 7 (1930); *Chem. Abs.*, 1931, **25**, 405.
[45] *Azer. Neft. Khoz.*, 1930, (11) 107; *Chem. Abs.*, 1931, **25**, 1066.
[46] *Neft. Khoz.*, 1929, **17**, 520; *Chem. Abs.*, 1930, **24**, 1730.
[47] *J.S.C.I., Japan*, 1931, **34**, Suppl. 58; *Chem. Abs.*, 1931, **25**, 2841.
[48] *Paliva a Topeni*, 1929, **11**, 85; *Chem. Abs.*, 1930, **24**, 4925.
[49] *Ind. Eng. Chem.*, 1930, **22**, 1274.

showed that similar results can be obtained by increases in temperature or time, and that a temperature increase of 17° C. approximately halves the time of conversion. More recently these authors[50] have stated that the cracking of pure hydrocarbons is probably a mono-molecular reaction, and have calculated the effect of temperature on the reaction rate. It was found that at 450° C. (842° F.) a doubling of the reaction rate required a temperature rise of 14° C. (25° F.); at 600° C. (1112° F.) a rise of 21° C. (38° F.).

A description of the difference between liquid phase and vapour phase cracking has been given by Sachs,[51] who states that the principles upon which a vapour phase plant is built are: the complete vaporisation of the oil prior to passing to the cracking zone, the imparting of heat to the dry vapours by commingling them with hot inert gases, and exposure of this hot mixture of gases to ceramic materials only. The reaction chamber is so designed as to allow time for the optimum once through conversion at about 1000° F. Pressure is unnecessary except to overcome friction and insure good circulation or to limit the volume. In the use of this process the yields of high anti-knock gasoline vary according to the cracking stock.

Osterstrom and Wagner[52] have studied the effects of temperature and pressure on the rate of cracking under conditions approximating those found in plant operation and have proved that:—

1. Up to two atmospheres pressure the only effect of pressure is to increase the time factor.
2. For a given time increase in temperature will increase the ratio of a fixed gas to motor fuel.
3. For a given temperature, increase in time will increase the ratio of gas to gasoline produced.
4. Between 1050° and 1150° F. change of time or temperature has little effect on quality unless time is so short as to give a recirculation ratio of at least 6 : 1.
5. Low vapour velocities result in high gas to motor fuel ratios.
6. The vapour-phase reaction is endothermic and requires large amounts of heat to maintain cracking temperatures.
7. Variation of charging stock causes much less variation in the gasoline product than in liquid phase cracking.

In a previous article Wagner[53] claimed that the "Gyro" vapour phase process produces a motor fuel comparable to benzole for blending purposes. The process is reported applicable to a wide

[50] Buffalo Meeting of A.C.S., September, 1930.
[51] *Refiner*, Jan., 1930, **9** (1), 70.
[52] *Proc. Amer. Petr. Inst.*, 1930, **11**, 1.
[53] *Refiner*, Nov., 1929, **8** (11), 80.

range of charging stocks with production of similar gasolines and gases. Average yields reported from gas oil are: motor fuel 60 per cent. and dry gas 30 per cent. The gas produced may be converted into a motor fuel of higher anti-knock value than the gasoline produced by the original vapour phase cracking, so the yields become approximately 75 and 15 per cent. respectively. Gasoline yields reported[54] on the latter basis for cracking of topped crude and still bottoms were 57 and 40 per cent. respectively.

De Florez[55] has described an installation and states[56] that by gradually raising the pressure, more secondary cracking takes place, and the character of the distillate changes towards the type usually attributed to liquid phase cracking, the change becoming well defined when pressures of 50–60 lb. per square inch are reached, the temperature remaining constant. Furthermore he states[57] that increased pressure increases the yield of gasoline and improves its colour and treating properties. Moreover, the anti-knock value of the distillate is not appreciably decreased with pressure. More recently Swanson[58] has described the essential features of operating a unit to produce coke.

Ziegenhain[59] has pointed out that the Pratt installation allows the use of any normal charging stock and the production of a fuel oil meeting specifications. Krase and Ziegenhain[60] cite an example of the cracking of Mid-Continent crude from which 42 per cent. of motor fuel was produced which, when blended in equal proportions with average Mid-Continent straight-run gasoline, produces a motor fuel of 40 per cent. benzole equivalent. Eighty per cent. of the liquid products were recovered direct from the plant.

Reid[61] reported the cracking of a Mid-Continent topped crude to produce 42 per cent. of a gasoline having a benzole equivalent of 80 per cent., 38 per cent. of cracked fuel oil and 20 per cent. of coke.

Mills[62] has described the Hoge cracking unit, and reports high yields of gasoline from Kern County crude oil.

Staley[63] reports that a 250 barrel Leamon vapour-phase cracking unit in Canada uses gas oil as charging stock.

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[54] *Refiner*, June, 1930, **9** (6), 70.
[55] *Nat. Petr. News*, 4.12.29, **21** (49), 33.
[56] *Oil and Gas J.*, 5.12.29, **28** (29), 132.
[57] *Proc. Amer. Petr. Inst.*, 1930, **9**, 111.
[58] *Oil and Gas J.*, 5.3.31, **29** (42), 95.
[59] *Oil and Gas J.*, 16.10.30, **29** (22), 38.
[60] *Chem. and Met. Eng.*, 1930, **37**, 624.
[61] *Refiner*, Nov., 1930, **9** (11), 81.
[62] *Refiner*, Jan., 1931, **10** (1), 89.
[63] *Petr. Eng.*, Oct., 1931, **3** (1), 40.

IV. Cracking in Liquid-Vapour Phase and Vapour Phase.

Fussteig[64] describes the Weymann system for cracking oils, which employs a still consisting of two tube banks with an atomiser between them. In the first bank the oil is cracked under pressure in liquid phase; in the atomiser cylinder it is vaporised with reduction of pressure; and cracking is completed in vapour phase in the second tube bank. High yields of cracked gasoline, together with high-grade lubricating oils and good paving asphalt, are claimed to be obtained from Rumanian and Polish oils.

V. Electrical Cracking.

The use of the corona discharge as an accelerator in vapour-phase cracking is described by Rowland[65] from the results obtained in an experimental plant. Two theories are advanced as to the actual effect of the corona discharge. First, it is thought that by more perfect ionisation of the vapours than can be effected by heat alone, changes in the molecules take place more rapidly. Secondly, the discharge, acting as an agitator, keeps the vapours in a state of great turbulence, driving them against the heated walls of the tube, and so assisting the cracking process. Later, Rowland[66] found it feasible to consider an electron moving through a considerable distance in space, either carrying with it or driving before it a molecule of hydrogen in vapour form, and finally reaching a surface which permits no further movement of the oil vapour molecule, but which readily absorbs the electron.

Fester and Christen[67] discuss the cracking of mineral oils in the presence of the electric arc operating between electrodes of either nickel or iron. The composition of the cracked gases and distillation ranges of the cracked distillates are reported.

VI. Cracking with Oxidation.

A modification of the process of cracking heavy oils by partial combustion with air is claimed by Chilowsky[68] to result in smooth operation without production of carbon and reducing tar production to a minimum. This result is obtained, he claims, by "insufflating" the oil in contact with air, pre-heating the air to a temperature higher than the combustion point of the oil, *i.e.*, 500 to 700° C., and maintaining the walls of the combustion chamber at a temperature of about 1000° C. It is claimed that this method of cracking

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[64] *Petr. Z.*, 1931, **27**, 520.
[65] *Oil and Gas J.*, 27.11.30, **29** (28), 38.
[66] *Elec. Eng.*, 1931, **50**, 288.
[67] *Z. Elektrochem.*, 1930, **36**, 17; *Chem. Abs.*, 1930, **24**, 4382.
[68] *Ann. des Comb. Liq.*, 1930, **5**, 547.

makes it possible to use the product in motor trucks, the composition of the fuel being such that the compression may be raised to 8 : 1 without inconvenience. These results have been obtained with a gas oil boiling between 230 and 370° C.

VII. Treating of Cracked Products.

(*a*) *General.*—One of the problems involved in treating of cracked distillates—*i.e.*, removal of sulphides—has been attacked by Borgstrom, Bost and McIntire,[69] by testing the effect of various refining agents on the removal of pentamethylene sulphide from solution in naphthas. Sulphuric acid, mercuric salts, permanganate and sodium hypochlorite almost completely remove the sulphide. Silica gel, aluminium chloride and liquid sulphur dioxide remove a part of it, and metallic sodium does not appreciably affect it.

In agreement with the above are the results of Youtz and Perkins,[70] who found that sulphuric acid thoroughly removes the lower alkyl sulphides from naphtha solutions. With aluminium chloride, however, the normal sulphide is much less completely removed than the secondary and iso-butyl sulphides. The effect of fused caustic alkali, at 650° F., was also noted. Mercaptans in crude naphthas were removed completely, but the alkyl sulphides, especially the lower ones, were only slightly affected. The authors suggest that differences noted in the fused alkali treatment are not concerned with structure but with molecular weight, while with aluminium chloride the opposite is true.

In connection with these two studies it is interesting to note that Cannon[71] states that the two most common methods used in treating California sour pressure distillates involve sulphuric acid and an oxidising agent such as hypochlorite or plumbite.

Schmitz[72] has made a comparative study of several reagents used in refining cracked gasoline, and has found that gasoline, treated cold with 30° Bé. sodium hydroxide, or hot with fullers earth, showed discoloration and gum formation on standing, even in the dark. He states that the washing with alkali should be followed by a dilute acid wash. Further, he found that a gasoline of excellent colour and stability was obtained by a vapour-phase purification over minette (Fe_2O_3). Various brands of fullers earth instead of minette were less effective. Dry calcium chloride and sodium hydroxide were practically ineffective.

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[69] *Ind. Eng. Chem.*, 1930, **22**, 87.
[70] *Ind. Eng. Chem.*, 1930, **22**, 610.
[71] *Petr. World and Oil Age*, 1930, **27** (6), 95.
[72] *Erdol u. Teer*, 1930, **6** 493 510

With regard to the gum problem, Rue and Espach[73] have stated that gasoline, sweetened with hypochlorite or doctor, may contain more gum than the untreated samples unless the quantities of sulphur or hypochlorite are carefully controlled. The gum content, however, may be reduced by slow distillation. Gum in acid treated distillate may be reduced by washing the rerun distillate with water or alkali, and inhibitors stabilise the oil against gum formation.

Bespolov[74] has reported that a cracked gasoline from Baku, after treatment with sulphuric acid and a month of storage, deteriorated with respect to colour, and a colourless product was obtained by vapour-phase refining with floridin. Furthermore, he states that a combination of acid and vapour-phase treating methods is the best solution of the refining problem.

Schmitz[75] has concluded from a series of investigations that the following procedures are always more advantageous than the usual present-day refining methods, particularly as regards the odour of the gasoline and the almost complete suppression of later formation of gum in the gasoline: "(1) Properly fractionating the cracked gasoline so as to obtain directly a gasoline having a boiling point close to that of the finished product; (2) superheating the cracked gasoline under definite conditions (varying with the type of gasoline) before it leaves the rectifying column; (3) following the superheating by a treatment with a dehydrated metal oxide as the first refining agent, which may be mixed with either silica gel or iron oxide gel, both of which help to remove sulphur from the gasoline; (4) completely decolorising by one of two methods the gasoline thus treated: (*a*) passing the gasoline vapour over a suitable decolorising earth (preferably floridin); and (*b*) after treating with dehydrated oxide, condensing the gasoline, giving it a light refining with acid and decolorising by filtration through or shaking with floridin or activated earth (the two treatments may be combined by introducing the vapours at the top of a tower containing floridin above and dehydrated oxide below); (5) superheating the crude cracked gasoline always gives rise to the liberation of hydrogen which may be used directly for a supplementary hydrogenation, by known methods, of the superheated gasoline, or may be separated and used for any other purpose. This refining process is practical, simple and inexpensive."

(*b*) *Treating Cracked Distillates.*—(1) *Acids.*—Pierce[76] has investigated the factors involved in acid treating cracked distillates and found that the best reduction of sulphur, best colour and lowest

[73] *Oil and Gas J.*, 6.3.30, **28** (42), 186.
[74] *Azer. Neft. Khoz.*, 1931, (5) 70; *Chem. Abs.*, 1931, **25**, 5548.
[75] *Chimie et Industrie*, March, 1931, **25**, Special No., 355.
[76] *Nat. Petr. News*, 12.11.30, **22** (46), 121.

formation of sulphuric acid compounds, is obtained when the oil is contacted from three to five minutes. Acid formation was reduced and colour was much improved by using 20 per cent. steam during distillation. Storage before rerunning improves the colour and reduces the formation of acid at the rerun stills. A low temperature treat gives better colour and less formation of acid derivatives, but a high temperature treat gives lower sulphur. Settling time increases the formation of acid compounds and improves the colour but lowers sulphur only slightly.

A process[77] consisting of a primary treatment with 30 per cent. sulphuric acid followed by one with 70–80 per cent. acid at temperatures varying between 50 and 150° has been described. The primary treatment removes the most reactive substances, so that the more concentrated acid reacts with less violence. Finally, 40° Bé alkali is used which removes all substances of acidic nature. This procedure yields gasolines of excellent quality and a sulphur content of less than 0·1 per cent. The method is claimed to be superior to that of adsorption which polymerises the more active compounds which are not necessarily those constituents which produce coloration and gum upon storage.

Pothoff[78] has reported that solution and polymerisation losses from acid treating increase with the quantity of acid used, but the ratio between these losses was smaller for dilute acid. The maximum colour of 25 was obtained when 10 lb. of 66° Bé and 5 lb. of 60° Bé acid were used. The gum content generally decreased with increase in acid, but was erratic. The knock rating decreased with increase in quantity of acid. Increase of contact time has a better effect on gum but a worse effect on colour and increases the losses.

In agreement with the above is the statement of Bespolov[79] that more concentrated acid produces greater polymerisation. Further, he states that an oil partly polymerised by storage produces, on treatment with acid, polymers that are darker in colour but are otherwise quite similar to those obtained by direct action of sulphuric acid. Oil heated during treatment yields less polymers, which in appearance and properties are quite different from those obtained from freshly distilled oils.

Bogoslovskii[80] has asserted that treatment of cracked gasolines with acid and alkali is more desirable commercially than vapour-phase refining with floridin, which yields an unstable product.

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[77] *Petr. Z.*, 1930, **26**, 782.
[78] *Oil and Gas J.*, 5.3.31, **29** (42), 141.
[79] *Neft. Khoz.*, 1929, **16**, 730; *Chem. Abs.*, 1930, **24**, 1731.
[80] *Azer. Neft. Khoz.*, 1930, (3) 74; *Chem. Abs.*, 1930, **24**, 3106.

Willson[81] has described a commercial treating installation which consists of acid treatment followed by clay contacting.

(2) *Alkali.*—Vesselovsky and Kalichevsky[82] have studied the action of potassium and sodium hydroxides on elementary sulphur and mercaptans dissolved in naphtha. The alkalies dissolved in ether, absolute ethyl and isopropyl alcohol or commercial isopropyl alcohol remove free sulphur by the formation of sulphides and thiosulphates. However, upon allowing the solutions to stand in the presence of air, free sulphur is formed by the oxidation of the above products. Mercaptans are removed quantitatively by means of alcohol solutions of the two alkalies, mercaptides being formed. When the mixtures are allowed to stand, the mercaptides hydrolyse partially and mercaptans pass into solution.

Billheimer and Reid[83] have stated that mercaptans in alkaline solution decompose in a definite manner, three simultaneous reactions taking place :—

$$RSH + 2\,NaOH \rightarrow ROH + Na_2S + H_2O$$
$$2\,RSH + 2\,NaOH \rightarrow R_2S + Na_2S + 2\,H_2O$$
$$CH_3CH_2SH + 2\,NaOH \rightarrow CH_2 = CH_2 + Na_2S + 2\,H_2O$$

In the case of butyl mercaptan about half of the product is decomposed in 2 hrs. at 260° with 3N sodium hydroxide. The octyl and nonyl mercaptans yielded insoluble sodium derivatives. The total decomposition decreases as the number of carbon atoms increases, and the secondary mercaptans react more rapidly than the corresponding primary derivatives.

Atchison[84] has described a continuous pressure distillate treater in which the distillate is washed with caustic soda. The product after redistillation has the following properties : sulphur 0·10 per cent., gum 4 to 5 mgs., 23 to 25 colour, good corrosion test and fair odour.

(3) *Salts.*—The reactions of some mercaptans with alkaline sodium plumbite have been studied by Ott and Reid,[85] who draw the following conclusions : (1) The quantity of sodium bisulphide formed decreases with increase of molecular weight of secondary mercaptans, and is quite unimportant in the case of primary mercaptans. (2) The lead compounds of the secondary mercaptans are more soluble than the corresponding primary compounds. In the primary series, solubility decreases with increase in molecular weight ; in the secondary the reverse is true. (3) In the primary

[81] *Oil and Gas J.*, 18.12.30, **29** (31), 38.
[82] *Ind. Eng. Chem.*, 1931, **23**, 181.
[83] *J.A.C.S.*, 1930, **52**, 4338.
[84] *Petr. Eng.*, Feb., 1930, **1** (5), 176.
[85] *Ind. Eng. Chem.*, 1930, **22**, 878.

series the basic lead compounds are more soluble than the neutral salts; in the secondary series the reverse is true. (4) The relative quantity of the basic lead compounds increases with increase in concentration of the plumbite solution. (5) The lead compounds are generally light stable when dry. When moist they decompose, yielding lead sulphide and hydrolysis products.

It has been reported[86] that cracked gasoline, which has been treated with doctor solution, shows a tendency to deteriorate in colour, especially in the presence of certain metals such as copper. The addition of acid changes the reaction of the gasoline from basic to acidic, and the yellow colour is not produced on standing.

Lachman[87] has studied various phases of the doctor sweetening process, and has suggested some improvements in its application.

A method of sweetening pressure distillates by means of copper ammonium hydroxide has been discussed by Cook,[88] who states that while the method is more expensive than the plumbite method, it has the advantage that the oils so sweetened are stable, have a lower sulphur and gum content, good colour, and there is no necessity for further treatment of the finished gasoline.

Borgstrom and McIntire[89] have studied the effect of various inorganic salts on the mercaptan sulphur in naphthas and found that the only salt in the group (which did not include mercurous nitrate) which gave an "absolutely" sweet naphtha was mercuric acetate. In a more recent paper the same authors[90] indicate that mercuric chloride is less active and mercurous nitrate is more active than mercuric acetate.

(4) *Adsorbents.*—Gerstenberger[91] has reported that a finished gasoline of higher anti-knock qualities is obtained when the Gray vapour phase process is substituted for sulphuric acid and re-running. The pressures may be varied, and an increase in pressure increases the life of the clay. It is suggested, however, that this result is due to the higher temperature obtained at the higher pressures. A product of 30 colour containing 0·9 to 5 mg. of gum has been obtained by this process, but it must be sweetened. Furthermore, all oils do not respond to this vapour phase treatment.

In a more recent article Gerstenberger[92] has reported that, contrary to previous experiences, the gum content was consistently decreased with increased use of the fuller's earth in a Gray tower.

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[86] *Petr. Z.*, 1930, **26**, 56.
[87] *Ind. Eng. Chem.*, 1931, **23**, 354.
[88] *Petr. Eng.*, Jan., 1931, **2** (4), 163.
[89] *Ind. Eng. Chem.*, 1930, **22**, 249, 250, 253.
[90] *Ind. Eng. Chem.*, 1931, **23**, 321.
[91] *Nat. Petr. News*, 11.2.31, **23** (6), 59.
[92] *Oil and Gas J.*, 5.3.31, **29** (42), 140.

As above, the writer ascribed these results as well as the long life of the adsorbent to increased pressure and temperature. Furthermore, he reports that unless the sulphur used in the sweetening process is properly controlled the gasoline becomes cloudy, but this may be prevented by adding ammonia, aniline or Du Pont No. 2 chemical

Fradkin and Strom [93] have reported that the use of fuller's earth in vapour phase yields 91·1 per cent. finished gasolines, while 0·2 per cent. of the earth is consumed. During the process the earth is continuously heated by flue gas, the temperature being kept at 230–5° C. The product has a Stammer colour of 2·1, 0·3 per cent. gum and a satisfactory doctor test.

Brooks [94] has found that pronounced ability to cause polymerisation of certain hydrocarbons is common to a large number of sedimentary rocks of Oklahoma and several—the Sylvan shale, the Red Beds clay and Tertiary clays—were nearly equal to the best grades of fuller's earth.

Ginsberg and Markariants [95] have made a study of treating of cracked distillates with Surakhani clays and found that the greyish-green carbonate containing clays from lower strata gave good results when heated to 120° C. Clays activated by acids were unsatisfactory. The clay treatment alone was insufficient but additional treatment with 0·1 to 0·5 per cent. of sulphuric acid yielded satisfactory gasoline.

Grigorjew and Polinkowskaja [96] state, on the other hand, that fuller's earth cannot be replaced by Russian earths for the refining of cracked gasoline. An oil decolorised by the latter takes on the original colour when exposed to light for three months in a closed vessel.

(5) *Metals.*—The preliminary results of an investigation carried out with the object of studying the reactions of sulphur compounds in petroleum in the presence of contact catalysts alone, or with the addition of hydrogen, have been published by Elgin, Wilder and Taylor [97] and Elgin.[98] Experiments were made at 300° and 400° C. at atmospheric pressure. In the case of a sulphur-free nickel catalyst all sulphur could be removed from naphthas in the form of vapour. However, with continued use the catalyst became less efficient in its action, but it eventually reached a steady state, and then its effectiveness in reducing the sulphur content

[93] *Neft. Khoz.*, 1930, **18**, 445; *Chem. Abs.*, 1931, **25**, 1979.
[94] *Petr. Eng.*, 1930, **1** (9), 191.
[95] *Azer. Neft. Khoz.*, 1930, (10) 93; *J.I.P.T.*, 1931, **18**, 109A.
[96] *J. Chem. Ind.* (*Russian*), 1929, **5**, 943; *Chem. Zentr.*, 1929, **100**, II, 1497.
[97] *Ind. Eng. Chem.*, 1930, **22**, 1284.
[98] *Ind. Eng. Chem.*, 1930, **22**, 1290.

became constant. It was noted that fresh nickel catalyst was able to absorb sulphur from the naphthas in liquid form after they had been passed in vapour form over the catalyst. The addition of hydrogen increased the effectiveness of the catalyst in removing sulphur. All mercaptans were removed, the product obtained throughout the run being sweet to doctor with each naphtha, an improvement on the result obtained without hydrogen.

The action of an iron catalyst showed a similar type of behaviour as nickel, but was considerably less effective. It did not remove sulphur completely at any stage.

Other properties of the naphthas, besides sulphur content, were appreciably altered. The odour was considerably improved in most cases, and all colour could be removed from the naphthas in liquid form.

The mercaptans most readily eliminate sulphur as hydrogen sulphide, while the removal of thiophene presents a much more difficult problem by this method. Since it is known that the thermal decomposition of mercaptans and sulphides result in the formation of thiophene, it appears in general that the sulphur content of cracked naphthas will be more difficult to reduce by the present method than will that of straight-run naphthas.

(6) *Distillation.*—Schmitz [99] has stated that cracked gasoline should be carefully fractionated previous to refining, since the heat of the fractionation produces no gum and gives a product which is permanently stable to light.

Gregory [100] emphasises the reduction of evaporation losses by separation of propane and lighter fractions, and in some cases butane, before treating cracked distillates. More recently the same author [101] has described a commercial operation in which the pressure distillate is stabilised by fractionation and the gasoline in the cracked gas is removed by absorption.

Another commercial operation of this sort has been described by Ziegenhain.[102] A Louisville, Kentucky, refinery secures good colour and colour-stability in its cracked gasoline by heating the pressure distillate in a coil before flashing off the gasoline in a large tower.

(7) *Inhibitors.*—The effect of anthracene, gum camphor, Du Pont No. 2 and aniline in stabilising cracked distillates has been studied by Sullivan.[103] The results indicate that all have some

[99] *Mat. grasses*, 1930, 22, 9016; U.S.B.M. Bibliography, April, 1931, p. 48.
[100] *Petr. Eng.*, Mar., 1930, 1 (6), 48.
[101] *Petr. Eng.*, Aug., 1930, 1 (12), 157.
[102] *Oil and Gas J.*, 3.7.30, 29 (7), 38.
[103] *Oil and Gas J.*, 5.3.31, 29 (42), 156.

inhibiting effect on colour or gum or both, but the author states that it is not possible to predict how inhibitors will react when applied to different gasolines.

Using the accelerated oxidation test Egloff, Faragher and Morrell[104] have found that aniline, dimethylaniline, urea, hydroquinone and anthracene are effective in checking gum formation. With regard to colour stabilisers, it was found that the action of any particular inhibitor varied considerably for different gasolines.

In a more recent paper by Egloff, Morrell, Lowry and Dryer[105] the following facts were discussed. Tricresol, hydroquinone, and Du Pont No. 8 are good inhibitors, giving similar results. Phenol is a weak inhibitor, its activity being intensified, however, by the introduction of alkyl, hydroxy, or amino groups in the ortho or para-position. Amines behave similarly to the phenols, phenyl-alpha-naphthylamine being the only valuable member of the group. Aromatic halogen compounds were not effective unless they contained another inhibiting group. Chloro-hydroquinone is a good inhibitor and more useful than the protectively superior hydroquinone, on account of its greater solubility in gasoline.

In a paper on the chemical nature of gum-forming constituents Flood, Hladky and Edgar[106] discussed the effect of certain inhibitors on the polymerisation of olefines.

Naphthali[107] has summarised the work of various investigators to substantiate the theory that gum formation is associated with oxidation, probably with the initial formation of organic peroxides, and is inhibited by the addition of various substances, such as ethyl alcohol and hydroquinone.

(9) *Reviews on Treating Cracked Distillates.*—A series of papers reviewing the use of sulphuric acid, plumbite, hypochlorite, fuller's earth and sulphur dioxide as treating agents has been published by Morrell.[108]

The problems encountered in the purification of cracked gasoline have been discussed by Naphthali[109] with reference to the use of plumbite, hypochlorite, sulphuric acid, solvents and chlorine.

Japour[110] has written a brief survey of the use of hypochlorite, fuller's earth, sulphuric acid, sodium plumbite and hydrogenation in the treatment of cracked gasoline.

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[104] *Oil and Gas J.*, 5.12.29, **28** (29), 116.
[105] Buffalo Meeting, Am. Chem. Soc., September, 1931.
[106] Cincinnati Meeting, Am. Chem. Soc., September, 1930.
[107] *Chem. Ztg.*, 1930, **54**, 371.
[108] *Nat. Petr. News*, 17.12.30, **22** (51), 61; 24.12.30, **22** (52), 49; 31.12.30, **22** (53), 46; 7.1.31, **23** (1), 63; 14.1.31, **23** (2), 57; 21.1.31, **23** (3), 51.
[109] *Brenn. Chem.*, 1930, **11**, 282.
[110] *Petr. Eng.*, Nov., 1930, **2** (2), 122.

(c) *Treating of Residues from Cracking.*—It has been reported [111] that residuum is freed from its sludge by dilution with pressure-distillate bottoms, filtration, and distillation from the diluent. One volume reduces the sludge in a Dubbs cracked residuum from a California crude oil from 12 to 1 per cent., two volumes reduces it to 0·3 per cent.

Goodwin [112] has described an acid flocculation-filter method for the removal of solids, found in most cracked residua, to produce a satisfactory fuel oil and a dry filter cake suitable for burning with refinery coal or coke.

Note.—Those papers dealing with the treatment of residues to produce materials other than liquid fuels are to be found in the section on by-products of cracking.

(8) *By-products of Cracking.*—While gasoline is undoubtedly the chief product of the cracking process, the lighter and heavier products are being put to practical use in more and more varied ways, both directly as obtained from the cracking process and indirectly after special treatment.

A series of analyses of gases from the vapour phase cracking of fuel oil is reported by Markovich and Pigulevskii.[113] They give data on the characteristics of three fractions of the gas, comprising a permanent gas fraction, a Blau gas fraction, and a light gasoline fraction. Their work was undertaken to determine the possibility of using cracked gas in the manufacture of synthetic chemical compounds to replace natural fats, for preparing glycols, perfumes, etc.

Fixed gases from the cracking process are marketed as domestic fuel after being prepared by processing through a gasoline recovery plant, having been first freed from hydrogen sulphide by scrubbing with soda ash.[114] Romoli-Venturi [115] investigated the chemical nature and industrial utilisation of these gases from the cracking process by compressing them to liquid products boiling from 20 to 100° C. (sp. gr. 0·65–0·75). He found them to be almost entirely diolefines and diacetylenes which he claims to be impossible for use as intermediates in the manufacture of alcohols, aldehydes or ketones.

The gaseous products from the cracking of gasoline by the Cross process, however, have been converted into alcohols by Pilat, Piotrowski and Winkler.[116] The original gases, containing

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[111] *Petr. Z.*, 1930, **26**, 284.
[112] *Nat. Petr. News*, 22.7.31, **23** (29), 46; 29.7.31, **23** (30), 45.
[113] *Neft. Khoz.*, 1930, **18**, 425; *Chem. Abs.*, 1931, **25**, 1979.
[114] *Refiner*, Nov., 1929, **8** (11), 122.
[115] *Ann. Chim. Applicata*, 1930, **20**, 18; *Chem. Abs.*, 1930, **24**, 2870.
[116] *Przemysl Chem.*, 1929, **13**, 208; *Chem. Abs.*, 1930, **24**, 1963.

10 to 12 volume per cent. of olefines, were first freed from water, sulphur and gasoline. The best yields of alcohols were obtained by using 80 to 85 per cent. sulphuric acid which, at 15–20° C. under two atmospheres, absorbs about 70 per cent. of the olefines present. Holzmann and Pilat[117] also report the conversion into alcohols of cracked hydrocarbons of initial boiling point 24–26° C. Their initial material contained 38 per cent. olefines. Treated with equal volumes of sulphuric acid at 0° C., 50 per cent. of the olefines were converted into alcohols. Addition of acetic acid improved the yield considerably. Tertiary alcohol formation was favoured by 75 per cent. acid, while secondary alcohols predominated with 85 per cent. acid.

Sulphuric acid treatment at —45° C. of the "amylene" fraction obtained from vapour phase cracking of petroleum is described by Markovich and Pigulevskii.[118] The original material contained 43 per cent. of dissolved gases. It was found that 75 and 66 per cent. acid dissolved more polymers than 85 per cent. acid and the low temperature used during saponification acted favourably on the yield of alcohols. From 12·8 to 25·5 per cent. of the gas was converted into alcohols.

The successful production of synthetic lubricating oils by the polymerisation of olefines with aluminium chloride has been described by Sullivan[119] et al. The olefinic stocks in many cases were petroleum-cracked distillates, including those obtained from cracking Winkler gas oil, wax-free Mid-Continent gas oil, and Pennsylvania mineral seal oil. Polymerisation was carried out at temperatures of 130–135° F. (54·5–57·2° C.), while agitating with the catalyst for 30 hours. About 3 per cent. by weight of aluminium chloride was the optimum amount of catalyst.

Piotrowski and Winkler[120] carried out a number of experiments on the production of secondary and tertiary monochlorides from a cracked gasoline fraction containing about 31 per cent. of amylenes. They used hydrogen chloride gas at various temperatures with and without catalysts. Best yields were obtained by starting the reaction at 70° C., when chiefly secondary chloro-derivatives were obtained, and completing it at 150° C., when tertiary products preponderate. Treatment of 2 litres of gasoline in the presence of active carbon and zinc chloride gave 450 ml. of a mixture of chlorides, a yield of 75 per cent.

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[117] *Przemysl Chem.*, 1929, **13**, 455; U.S.B.M., Bibliography, August, 1930, p. 41.

[118] *Neft. Khoz.*, 1930, **18**, 627; *Chem. Abs.*, 1931, **25**, 405.

[119] *Ind. Eng. Chem.*, 1931, **23**, 604.

[120] *Przemysl Chem.*, 1931, **15**, 25; *Chem. Zentr.*, 1931, **102**, I, 2455.

Heavy oils from cracking have been used successfully as carburetting agents, according to Dashiell,[121] who describes their use in several different companies.

Morrell and Egloff[122] report that specification road oils can be made directly from the cracking process operated by the "flashing" method. The road oils are made from the cracked residue. Examples of road oils obtained from flashed residues of cracked Mid-Continent and Montana oils are described.

Asphalts may also be obtained from the flashed residues from cracking operations according to Egloff and Morrell.[123] They report the adaptation of the cracking process to produce gas, gasoline and asphalt. It is thought that in the cracking process, where oxygen is absent and sulphur may be present in only small amounts, polymerisation and condensation accompanied by dehydrogenation and intramolecular change probably produce the asphalt. Tabulated data compare asphalts obtained from "flashing" Kentucky and Mid-Continent stocks. These asphalts meet A.S.T.M. specifications and may be varied by blowing with air or steam.

Schulz[124] reports excellent results for the burning of pulverised petroleum coke from the Dubbs cracking process. The coke ignites at a lower temperature than powdered coal, the flame propagates faster, the ash content is lower, it is more easily pulverised into uniform particles, and the cost of upkeep of the pulverisers is lower than for coal.

Petroleum oils which can be substituted for linseed oil have been obtained by Bespolov[125] from a cracked residue. The tar obtained by cracking heavy gasoline fractions at 550° C. under a slight vacuum is redistilled and mixed with a fraction boiling below 170° C. and is then treated with sulphuric acid to produce the drying-oil.

9. Cracking Equipment.

(*a*) *Plant Arrangement.*—The arrangement of the equipment in a cracking plant has an important bearing upon the efficiency of the plant from the point of view of labour saving, prevention of excess coke formation with consequent longer running time, simple control, and safety.

Huff[126] discusses the expansion of the field of usefulness of the cracking process in flexibility and control with improvements

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[121] *Gas Age-Record*, 1931, **67**, 223.
[122] *Nat. Petr. News*, 15.4.31, **23** (15), 59.
[123] *Ind. Eng. Chem.*, 1931, **23**, 679; *Mon. Petr. Roumain*, 1931, **31**, 483.
[124] *Refiner*, Jan., 1930, **9** (1), 55.
[125] *Azer. Neft. Khoz.*, 1929, (11) 42; *Chem. Abs.*, 1930, **24**, 3105.
[126] *Oil and Gas J.*, 9.10.30, **29** (21), 138.

in design and fabrication of cracking equipment. He describes the non-residuum method of cracking producing up to 72 per cent. of gasoline, coke and gas, as well as the flashing method, which produces a lower yield of gasoline but a fuel oil residuum. He also discusses means for corrosion protection by the use of resistant linings and surfaces or neutralisation of the corrosive constituents in the oil with alkali, lime, ammonia, etc.

The description by Rowe[127] of a new Canadian refinery emphasises the compactness of design which is such that the control of operations is effected with the minimum number of men. The plant combines topping, low and high-pressure cracking, and stabilisation in one operation. Another refinery of compact design is one at Denver, Colorado, reported by Fenex,[128] to combine skimming, cracking and other features in one unit. This plant operates entirely on electrical power, as does a Tyler, Texas, skimming and cracking plant described by Albright.[129] The rebuilding of an old plant according to modern design, as told by Foster,[130] has also resulted in considerable economies, the units operating for 500 hours without coke formation.

According to Willson[131] one refiner operating on California crude oils has effected considerable economies by the installation of separate equipment for treating straight-run gasoline, pressure distillate, and cracked gasoline.

Improved efficiency and centralised control in the cracking plant is claimed by de Florez[132] for the use of a new remote control device which uses self-synchronizing alternating current motors which remain accurately in phase. The control system, in cracking installations, has been applied to relief valves reducing the pressure from the reaction chamber into the bubble tower or from the bubble tower to the condenser, and having this pressure release controlled by the operator on the board.

The running of de Florez cracking units to coke has been accomplished, according to Swanson,[133] by placing two "coke drums" in the plant between the heater and the first tower, the characteristics of the coke being easily controlled by the temperature in the drums. A long operating cycle and gasoline of high octaine number are reported.

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[127] *World Petr.*, 1931, **2**, 610.
[128] *Oil and Gas J.*, 7.5.31, **29** (51), 70.
[129] *Refiner*, July, 1931, **10** (7), 71.
[130] *Nat. Petr. News*, 23.4.30, **22** (17), 73.
[131] *Oil and Gas J.*, 1.1.31, **29** (33), 25.
[132] *Oil and Gas J.*, 10.4.30, **28** (47), 124.
[133] *Oil and Gas J.*, 5.3.31, **29** (42), 95.

A high degree of safety is possible with high pressure equipment, according to Williams,[134] who discusses points of proper installation and operation.

A series of articles by Matson[135] discusses many phases of guarding cracking operations from accident. He reviews the factors of personnel supervision, safety equipment and devices, hazards, unsafe practices and inspection, and takes up the problems of hazards from water in the cracking system and dangers from corrosion.

(*b*) *Corrosion.*—A series of investigations was made by Retailliau and Lang[136] on the causes of corrosion in the cracking plant, experimental results being checked by data from plant operation. Where a sulphur bearing charge is used, corrosion seems mainly to be due to the action of elementary sulphur during the cracking period, with additional corrosion by hydrogen sulphide and sulphur dioxide during the steaming period when the plant is being shut down. The mechanism of corrosion is thought to be the decomposition of organic sulphur compounds, liberating hydrogen sulphide which is decomposed at the temperatures used, into hydrogen and elementary sulphur which attacks the steel.

Whitman and Roberts[137] attribute corrosion in cracking equipment to hydrogen sulphide, either present in the raw material or formed during operation, and report that corrosion rate is affected by both temperature and concentration. Reaction is doubled by an increase of 25 to 30° F. They review the methods of corrosion protection including injection of chemicals such as lime, use of corrosion resistant alloys such as 18–8 chromium-nickel steel, and lining with cement, refractories, or other metals. They also cite the use of metal walls of excess thickness which are allowed to corrode until the minimum is reached.

An interesting method for reducing the hazard of failure from this last procedure is described by de Florez.[138] Emphasis is laid upon careful technique in the use of the simple idea. The method consists of preparing parts of conduits or vessels where failure might occur by drilling the walls of the equipment with small holes at fairly close intervals to a depth determined by the lowest

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[134] *Oil and Gas J.*, 6.3.30, **28** (42), 200.

[135] *Refiner*, Jan., 1931, **10** (1), 97; Feb., 1931, **10** (2), 122; Mar., 1931, **10** (3), 164; May, 1931, **10** (5), 99; June, 1931, **10** (6), 110; *Oil and Gas J.*, 23.10.30, **29** (23), 38; 30.10.30, **29** (24), 66; *Petr. Times*, 1930, **24**, 755, 779, 839, 925.

[136] *A.P.I. Tenth Annual Meeting Proceedings*, **11** (1), Sec. III, 158, 1930; *Oil and Gas. J.*, 5.12.29, **28** (29), 120.

[137] *A.P.I. Tenth Annual Meeting Proceedings*, **11** (1), Sec. III, 150, 1930; *Oil and Gas J.*, 5.12.29, **28** (29), 94.

[138] *Oil and Gas J.*, 5.11.31, **30** (25), 22.

safe bursting limit. "When corrosion or erosion occur to thin the wall of the container, leakage will be evidenced at these drilled points, giving warning that a safety limit has been reached."

Lind[139] reports quantitative determination of material losses from corrosion in cracking plants. Weighed samples of steel were left in the dephlegmator of a Dubbs apparatus. Over a six months period it was found that Barsig steel was more corrosion-resistant than American steel, lasting half as much longer under the experimental conditions. Chrome steel outlasts both, its loss of weight in per cent. per day per square centimetre of surface amounting to only 4·6 per cent. of the loss of American steel and 7·19 per cent. of the Barsig steel.

The specific problems of corrosion affecting oil-vapour condensers are discussed by Pew[140] from the viewpoint of the effect of modern equipment design. The action of oxygen in the water on the water side of the condenser can be minimised by keeping the pH value above 10. The tubular condenser is used in preference to the submerged coil because of the enlargement of distillation and fractionating equipment. Importance of design of condenser and choice of construction materials is stressed.

A metal lining of 12 gauge 18–8 chromium-nickel steel bonded to the wall of a refinery reaction chamber is reported by Andrus[141] to have successfully withstood corrosion at high temperatures under high pressures. Morrell[142] discusses the successful use of non-metallic protective linings in the larger elements of refining equipment and especially in cracking equipment.

Corrosion-resistant materials from which cracking equipment may be constructed successfully have been the subject of metal research for some time. Mathews,[143] on the subject of recent developments in corrosion-resistant and heat-resistant steels, says that nickel-chromium-silicon steels are preferable for use at high temperatures. He recommends that all corrosion data should be expressed in depth of penetration in unit time, and describes tests of the time required to develop visible scale on various alloy steels. The use of various steels and alloys in cracking equipment, especially for cracking coil tubes, is reported by Egloff and Morrell,[144] who note that the type of stock used is a large factor in determining the relative values, to the refiner, of highly resistant, very expensive alloys and ordinary or heavy steels. In some cases the superior resistance of the alloy is over-balanced

[139] *Petroleum Z.*, 1930, **26**, 280.
[140] *Refiner*, May, 1931, **10** (5), 79.
[141] *Refiner*, Apr., 1931, **10** (4), 94.
[142] *Oil and Gas J.*, 20.3.30, **28** (44), 41; *Nat Petr. News*, 19.3.30, **22** (12), 64.
[143] *Ind. Eng. Chem.*, 1929, **21**, 1158.
[144] *Refiner*, Apr., 1931, **10** (4), 77.

by its excessive cost. Throughputs of the same charging stock for the life of alloy, heavy steel, and ordinary steel tubes are compared.

Mead, Shaffer and Camp [145] illustrate the increase of tube corrosion with increasing temperature. Chromium-nickel steel (18–8) tubes were used successfully at 700° F. in place of carbon steel tubes.

The injection of chemicals into the cracking apparatus has been used frequently to combat corrosion. Dickinson [146] advocates the introduction of lime into the charging stock and subsequent filtration of the residuum. Faught [147] reports the use of 25 lb. of lime per barrel of West Texas crude oil. Besides reducing corrosion, the lime was found to soften the coke formed.

Ammonia is utilised, according to Albright,[148] to combat corrosion in the line to the rerun unit by giving an alkaline reaction to the condensate from the processed pressure distillate. Another chemical reagent is reported by Ziegenhain,[149] as used in Beaumont, Texas. A naphthenic soap containing excess alkali is pumped into the tower with the distillate to reduce corrosion.

(*c*) *Cracking Apparatus.*—The development of cracking apparatus from the early days of its use has been reviewed by Burrell,[150] who notes the tendency in modern operation to minimise coke formation. The variation of cracking reaction with temperature is considered direct, and operating temperatures are given as 750 to 1000° F. for liquid-phase processes, 1050 to 1150° F. for vapour-phase processes and 1300 to 1700° F. for gas-making processes. Petty [151] discusses the latest types of refinery apparatus, including stabilisers, cracking and cracking-vacuum units, etc.

The theory of design of liquid-phase cracking apparatus is the subject of an article by Ryabuikh,[152] who develops formulæ on the assumption that cracking rate doubles for every 10° C.

Reid [153] reports the achievement of a 2000 hr. period on steam by the addition of a third soaking drum to the tube-and-tank cracking unit in an Ohio refinery, the drums being alternately cleaned every 10 days without disturbing the rest of the equipment. An improvement over the Vickers installation is claimed [154] for a new cracking unit in Baku, a more limited part of which is

[145] *Oil and Gas J.*, 6.3.30, **28** (42), 122.
[146] *Petr. Eng.*, 1930, **1** (9), 198.
[147] *Petr. Eng.*, 1930, **1** (9), 163.
[148] *Refiner*, Aug., 1931, **10** (8), 71.
[149] *Oil and Gas J.*, 20.3.30, **28** (44), 46.
[150] *Nat. Petr. News*, 12.2.30, **22** (7), 51.
[151] *Refiner*, Feb., 1931, **10** (2), 67.
[152] *Azer. Neft. Khoz.*, 1930, (12) 76; *Chem. Abs.*, 1931, **25**, 1979.
[153] *Refiner*, Jan., 1930, **9** (1), 58.
[154] *Azer. Neft. Khoz.*, 1931, (4) 127; *Chem. Abs.*, 1931, **25**, 5009.

under high pressure, *i.e.*, 75–80 atmospheres. The unit is claimed to yield 45 per cent. of gasoline by weight, processing 125 tons of stock in 24 hours.

Mayer[155] considers the coefficients of heat transfer of baths of molten metal used as heating media for cracking. The coefficient, he finds, is dependent upon specific heat and specific gravity as well as conduction. The best thermal effect is thought to be obtained when the oil is finely dispersed in the molten metal and the time of contact is adequately extended.

A suggestion to aid the avoidance of coke deposits within the cracking unit is offered by Obryadchikov and Velikanov,[156] who advocate the elimination of the reaction chamber in favour of the pipe still where, they claim, 80 per cent. of the gasoline is formed.

The replacement of the old shell still by the modern tube still is noted by Wallis,[157] and Primrose[158] describes two designs of tube stills. The convection banks are made of steel tubes with a cast iron extended surface on the outside, the ratio of outside to inside surface decreasing from the top rows downward. The radiant banks are directly over the furnace, these being formed of uncovered steel tubes and so arranged that the upper tubes are partly shielded from the furnace by the lower ones. In the second type of still the radiant bank has only two rows of tubes.

Design of cracking tubes is also discussed by Luster,[159] who describes creep determinations being made on metals and alloys adapted for use in tube stills. Tests can be made at pressures up to 75,000 lb. per square inch over the range 800 to 1300° F. Data from these tests are being used to calculate the stresses set up in the tubes, including those accompanying temperature drop through the tube wall and those accompanying pressure difference between the inside and outside of the tube.

Furnace design, according to Darnell,[160] has permitted an increase of 30–40 per cent. in efficiency of shell stills. Increase in cracking furnace efficiency has also been claimed[161] by the use of a special air heater which is used both on Dubbs and Cross cracking units with success. "A cracking unit, having a throughput of 7200 barrels per day, is operated at a very high thermal efficiency by means of the air heater. The inlet temperature is

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[155] *Petr. Z.*, 1931, **27**, 141.
[156] *Neft. Khoz.*, 1929, **16**, 370; *Chem. Abs.*, 1930, **24**, 1206.
[157] *Chem. and Met. Eng.*, 1930, **37**, 557.
[158] *Nat. Petr. News*, 8.10.30, **22** (41), 57.
[159] *A.S.M.E. Transactions*, Petroleum Mechanical Eng. Section, 1931, **53** (11), 161.
[160] *Petr. Mech. Eng.*, October, 1930, p. 73.
[161] *Petr. Eng.*, Feb., 1930, **1** (5), 112.

735° F. and the outlet temperature 940° F." A floor-tube radiant section in a cracking plant in Texas has been reported by Power[162] to have increased daily cracking capacity by 250 barrels.

Control of furnace temperature in oil-cracking units has been reviewed by Darnell.[163] Control by flue-gas recirculation is favoured to give milder action of the gas on the tubes, larger throughput with the same amount of heating surface, saving of fuel and increase in efficiency.

A detailed discussion of research work on the welding of containers for use in oil cracking has been offered by Jasper.[164] Welds in such apparatus are accurately inspected by a new development in the use of X-rays, as reported by Ancel St. John.[165] Welded pressure vessels up to 3 inches thick are successfully and rapidly inspected by this method.

Dixon[166] considers that further development of the cracking art to produce better motor fuels is now attendant upon the development of more serviceable metals. It is also important that refiners know the safe operating stresses for given temperatures with reference to plain carbon steel. Jenkins and Tapsell[167] have published tables showing strengths of various steel alloys at elevated temperatures.

10. General Reviews on Cracking.

A résumé of gasoline manufacturing by cracking has been written by Egloff,[168] in which he emphasises the conservation of crude oil due to cracking, and the properties and treatment of the product. Sava[169] has reviewed the industry in a similar manner, including a description of several of the well-known processes.

Burrell[170] has published a series of articles on cracking which cover a wide variety of topics, from the development of equipment to anti-knock properties of gasoline and the foretelling of cracking reactions by means of thermodynamics.

Another review dealing with the theory of cracking phenomena has been written by Graetz,[171] who deals with the effect of time, temperature, pressure, reaction medium and chemical constitution

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[162] *Nat. Petr. News*, 5.11.30, **22** (45), 51.
[163] *Nat. Petr. News*, 23.7.30, **22** (30), 83.
[164] *Mech. Eng.*, 1930, **52**, 193.
[165] *Iron Age*, December 18th, 1930.
[166] *Nat. Petr. News*, 1.7.31, **23** (26), 51; 8.7.31, **23** (27), 51.
[167] *Engineering*, 1931, **131**, 713.
[168] *Petr. Eng.*, 1930, **1** (midyear), 104.
[169] *Ann. des Mines* (*Rumania*), 1929, **12**, 513, 563; 1930, **13**, 23; *Petr. Z.*, 1931, **27**, 125, 157.
[170] *Nat. Petr. News*, November 20th, 1929 to May 28th, 1930.
[171] *Chimie et Industrie*, 1930, **24**, 271, 526.

of the hydrocarbons cracked. He also discusses the more important cracking processes which have found commercial application and the probable evolution of the cracking industry in the near future.

Prandtstetten[173] has discussed the composition of petroleum distillates and the reactions involved in cracking with a brief description of various pieces of apparatus. The yields obtained and the economic aspects are considered.

The gasolines from various cracking processes and the nature of certain blended fuels have been described by Maihle[173] with particular reference to anti-knock value. Fournel[174] has also described various distillates from the cracking process and noted the catalytic cracking methods of Sabatier and Mailhe. The cracking of crude oil and the nature of the products obtained have been discussed by Fleschner.[175]

Two papers[176] have been published which review the development of cracking, stating that it is possible to obtain anti-detonating motor fuels by low temperature cracking from any crude oil regardless of its composition.

Stavorinus[177] has reviewed the cracking of gas oil and Sedlaczek[178] has reviewed the patent literature dealing with cracking of various fractions of petroleum. Sedlaczek also has written a book, "Die Krackverfahren unter Anwendung von Druck," in which he reviews processes associated with the familiar names of Burton, Dubbs, Cross, *et al.* The details of construction and operation of the plants are summarised.

The cracking process and its importance has been discussed by Giua,[179] who includes the experiments of Contardi and Longhi on cracking in the electric arc.

Egloff[180] has surveyed the cracking of heavy oils and tars from the point of view of gas production. Strout,[181] on the other hand, has made coke formation and the various factors influencing it the subject of a review of developments in commercial cracking.

Jones[182] reported a group of cracking processes both liquid and vapour phase, and pointed out advantages and disadvantages

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[173] *Oesterr. Chem. Ztg.*, 1931, **34**, 73; *Chem. Abs.*, 1931, **25**, 4112.
[174] *J. Usines Gaz.*, 1930, **54**, 242; *Chem. Abs.*, 1930, **24**, 5993.
[175] *Bull. assoc. tech. fonderie*, 1930, **4**, 20; *Chem. Abs.*, 1930, **24**, 4914.
[176] *Chem. Tech. Rundshau*, 1930, **45**, 447; *Chem. Abs.*, 1930, **24**, 4620.
[176] *Revue Pétrolifère*, 1930, (392) 1350; ibid., 1931, (408) 107.
[177] *Het. Gas*, 1930, **50**, 345; *Chem. Abs.*, 1930, **24**, 5976.
[178] *Erdol u. Teer*, 1930, **6**, 431; *Chem. Abs.*, 1930, **24**, 5990.
[179] *Riv. chim. sci. ind.*, 1930, **1**, 33; U.S.B.M. Bibliography, April, 1930, p. 41.
[180] *Proc. Am. Gas Assoc.*, 1930, p. 1369.
[181] *Oil and Gas J.*, 5.12.29, **28** (29), 62.
[182] *J. Inst. Fuel*, 1930, **3**, 376.

of the different types of cracking. Berl and Lind [183] also reviewed various cracking processes both vapour and liquid-vapour phase. Patents, technical features of the processes and nature and yield of products obtained from various cracking stocks are included in their discussion.

A review of several vapour phase processes has been published by Ginzburg,[184] who emphasises their importance in the Russian oil industry.

The major tendencies in refinery technology development in 1929 have been summarised by David,[185] who points out that vapour phase cracking and treating was on the increase during that period. Brooks [186] has reviewed the progress made in American refinery technology during the year and a-half prior to March, 1930, and includes improved distillation equipment.

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[183] *Petr. Z.*, 1930, **26**, 1027.
[184] *Azer. Neft. Khoz.*, 1931, (4) 60; *Chem. Abs.*, 1931, **25**, 4694.
[185] *Nat. Petr. News*, 26.2.30, **22** (9), 40A.
[186] *J.I.P.T.*, 1930, **16**, 125.

Distillation and Fractionation Equipment.

By W. A. Peters, B.A., B.S. (Associate Member).

Introduction.

While several installations of bubble towers had been made in petroleum refineries prior to 1925, that date marks the beginning of the general use of efficient fractionating equipment in petroleum work. At first, bubble towers were installed on existing shell stills, although some new shell still batteries with bubble towers were constructed, but the pipe heater was rapidly demonstrating its superiority over shell stills for most work, and by 1928 practically all new installations comprised pipe heaters instead of shell stills.

In January, 1927, Ashworth[1] pointed out that a single flash or equilibrium vaporisation of a crude gave a greater percentage of distillate at a given temperature than successive flashes or differential vaporisation. While this fact is self-evident and had been the basis of various distillation processes in other industries for many years, the practical advantages of the single flash were not fully appreciated throughout the petroleum industry. In April, 1927, Leslie and Good[2] published quantitative data on the relative separations made by single and successive flashes. These data showed a theoretical advantage in the single-flash system, and this apparent theoretical advantage together with many undoubted practical advantages led to the installation of many single-flash systems.

By the end of 1929 the possibilities and also the limitations of the single-flash system were well worked out. It was found that a temperature of about 430° C. at the heater outlet could be maintained without causing trouble from coking, but that at this temperature there was enough cracking to result in the production of off colour kerosine and a loss of lubricating oil yields. For most crudes the maximum temperature which could not be exceeded without some results of cracking becoming noticeable was about 380° C. Since the heater outlet temperature determined the percentage which could be distilled with a practicable amount of steam, it became necessary, in several cases where no cracking was desired and in other cases where a particularly low yield of bottoms was required, to add a second or vacuum stage, thus making a double-stage flashing. In some cases where the arrangement of fractionating tower and condensers in the vacuum stage was such

[1] *J.I.P.T.*, 1927, **13**, 91.
[2] *Ind. Eng. Chem.*, 1927, **19**, 453.

as to make it impracticable to maintain a low pressure at the vacuum vaporiser, a third stage had to be added. Of course the two-stage atmospheric and vacuum unit was being developed before 1929; in fact several very large units were in operation by the end of 1929.

The next two years, 1930 and 1931, saw an increased development of the two-stage and even three-stage units, not only for topping and lubricating oil, but for re-run units of various kinds. The combination topping and cracking unit also came into more general use, and it may be said that the development of the multiple-stage distillation unit, using of course, pipe heaters and flash vaporisation for each stage, and the combination topping and cracking, or vis-breaker units, constitutes the outstanding feature of distillation practice in this period.

With this very brief picture of the general line of development in mind, it would be well to examine in detail, first, the progress made in theory of design and in details of equipment, and finally, examples of the newest types of units. In discussing the first two points, it will be convenient to consider heaters, fractionating equipment, control equipment, pumps and heat exchanger equipment separately.

Theory of Design.

Heaters.—By 1930, the so-called modern heater had been pretty well standardised. It was obvious that a modification of boiler practice in which a certain amount of heat was absorbed by direct radiation would be practical for oil heaters, and it was only necessary to determine how much heat should be absorbed by radiation and how much by convection to give the maximum practicable overall rate of absorption without coking or burning the tubes. Earlier work on boilers and transfer of heat from flames, together with the work of Alcorn and his associates on controlling radiant heat by using refractory muffles within which the fuel was burned, had given a very good basis for the first designs, and the last two years have seen very little change in standard heaters.

Various methods of heating oil in thin films have been proposed from time to time. For example, in the D'Yarmett still the oil is forced into a thin film on the inside of the heating tube by a mechanically operated rotor.[3] None of these methods have been practically successful, unless the very successful process of the Sun Oil Company for high vacuum distillation of lubricating oil in a mercury boiler may be included in this classification. Recirculation of flue gases to obtain more uniform rates of heating has been used with some success in certain special cases, but it is an open

[3] *Nat. Petr. News*, 25.3.31, **23** (12), 59.

question whether the recirculation would be justified if the heaters had been properly designed in the first place. By proper design of the radiant and convection sections it is possible to get a maximum optimum rate of heat input over a large proportion of the heating surface, so that there would seem to be no need for going to extra expense and complication of recirculating the flue gases.

H. C. Hottel[4], [5] has developed formulæ, based on theoretical considerations, for calculating the rate of absorption in the radiant tubes of heaters for various arrangements of the tubes. The results given by him are helpful in considering the theoretical design of heaters, but no actual plant data have been published checking the theoretical results. It is difficult to obtain accurate figures on the rate of heat absorption in different parts of a heater, so that the exact arrangement of side and roof tubes, for example, in the radiant section of a modern heater has been rather a matter of judgment than of exact calculation.

The optimum average rates for different types of operations are pretty well established. Under certain conditions rates of 12,000 B.Th.U., or even higher, absorbed per hour per square feet of radiant surface are entirely practicable, but lower rates are usually used where there is any danger of coking or scaling. Thus while a heater to run gas oil used for heating the reboilers in a re-run unit might operate indefinitely with an overall rate in the radiant section of over 12,000 B.Th.U. per sq. ft. per hour, the same heater, if used to heat the charge of pressure distillate, might coke up at this rate and would probably be designed for a rate of about 7000 B.Th.U. per sq. ft. In general the tendency over the last two years has been to put more surface in the radiant section and cut down the rate of heat absorption, thus permitting the heater to remain on stream for a longer period without cleaning.

Fractionating towers.—With towers, as with heaters, the recent period is noteworthy for the increased knowledge of the performance of specific units, obtained by observation of overall results, rather than by the application of fundamental theory. This lack of development of the theoretical side has been due to the extreme complexity of the problem and the difficulty of obtaining theoretical data.

The determination of the capacity of a column is a comparatively simple matter. A paper by Chillas and Wier[6] outlines the method of calculating the duty on a fractionating column for a single-flash topping operation. Valuable data on the amount of entrainment

[4] *Mechanical Engineering*, 1930, **52**, 699.
[5] *Trans. Am. Soc. Mech. Eng.*, 1931, **53** (14).
[6] R. B. Chillas and H. M. Wier, "Design of Fractionating Columns," *Ind. Eng. Chem.*, 1930, **22**, 206.

that may be expected is given, but, as this data was obtained by passing air through cold water, it cannot be applied quantitatively to an operating tower. Of course, it is known that at capacities well below the maximum considerable entrainment takes place in bubble towers. The maximum capacity from the standpoint of vapour load is reached when liquid is blown in a mass from one plate to the next, or when the pressure drop between plates is so high that reflux will no longer run down the down pipes. Alcohol rectifying towers, for example, are run close to this limit and at rates where there is appreciable entrainment, but, since the entrainment is small compared to the reflux, the only effect will be a very small decrease in the apparent plate efficiency, necessitating, say, the addition of one or two plates to a thirty-plate tower.

In the case of a scrubber where the amount of reflux is relatively small, or at the vaporiser section of a tower in which crude is flashed, or any other case where very little reflux is used, entrainment may be a serious factor, and the tower must be operated at rates low enough so that there will be no entrainment, or means must be used to prevent entrainment.

In the above-mentioned paper, Chillas and Wier describe baffles for removing entrainment. The use of such baffles would obviously permit some reduction in the diameter of a tower, but whether the saving due to reduction in diameter would compensate for the extra cost of the baffles is an open question.

The calculation of the number of plates required for a given separation is not so simple, and at the end of 1931 it is still customary, in America, to base the design in this respect more on past experience than on calculation. Definite progress has been made by Prof. W. K. Lewis and his associates in measuring the separating efficiency of a petroleum fractionating tower. Lewis and Wilde published data on tests of a commercially operating tower in 1928.[7] They noted then that the plate efficiency of the tower tested was higher than would be expected on the basis of former data on binary mixtures. In 1930, Lewis and Smoley published the results of further work[8] in which high results for the plate efficiency were again found. Their method in the later work was to use a volatile material, which could be easily analysed, as an indicator. With aniline as an indicator, the plate efficiency was 95 per cent. and with pinene it was 85 per cent. Both results were so much higher than would be expected that they tested the tower with a mixture of benzole and toluole. This gave an efficiency, in line with older data, of 59 per cent. They then tested the tower with a mixture of three components, benzole, toluole and xylole, obtaining a plate

[7] *Trans. Amer. Inst. Chem. Eng.*, 1928, 21.
[8] *Trans. A.P.I.*, Tenth Meeting, 1930, sec. 3, p. 73.

efficiency of 73 to 79 per cent. So far no explanation for the difference in efficiencies has been offered.

Shirk and Montonna[9] found that the plate efficiency of a small bubble tower tested with ethyl alcohol and water varied from 30 to 90 per cent., depending on the rate of distillation and the reflux ratio. Such a wide variation had not been reported previously, and it may be due to some peculiarity of the tower, which only had one bubble cap on each plate. Brewster[10] calculated the plate efficiency of a bubble plate by assuming that the interchange of material between vapours and liquid is analogous to an interchange of heat. His method brings out the fact that a plate where the reflux takes a long course from inlet to outlet will be more efficient than one on which the flow of liquid is shorter. This method is interesting and may prove helpful in explaining the discrepancies found in the other methods. Until these discrepancies have been cleared up it will be difficult to give trustworthy quantitative expressions for the efficiency of any tower.

Actually it is only required to know the comparative efficiencies of the various types of towers used. Recently, several Russian engineers[11] have been working on the use of equilibrium curves after the manner of McCabe and Thiele[12] for determining the separation to be expected in a given tower or system of towers. S. N. Obryadchikoff has developed this method to the point where it can be used to make comparisons of systems with different kinds of towers as well as for the design of fractionating systems. The method involves some more or less arbitrary assumptions and may not give a close figure for the efficiency of a plate, but it promises to be a great help in designing towers for new types of operation and in determining the soundness of some of the existing designs.

Control equipment.—The manufacturers of control equipment have spent much time and effort co-operating with refinery operators in the development of a good automatic temperature control. In the latest types of thermostatic controls made by several companies, the old difficulty due to "hunting" seems to be nearly eliminated, so that it is common practice to use automatic control on the reflux to all types of towers. Liquid level controls have also been greatly improved, and several can now be obtained that will continue to operate smoothly with little care. The automatic recording flow controller has also proved its value on petroleum distillation units. Aside from these instruments,

[9] *Ind. Eng. Chem.*, 1927, **19**, 907.
[10] *Oil and Gas J.*, 3.4.30, **28** (46), 41, 143.
[11] L. T. Hachatoroff, *Neft. Khoz.*, 1928, No. 8, p. 627; A. M. Trigvoboff *Azer. Neft. Khoz.*; S. N. Obryadchikoff, pamphlet.
[12] McCabe and Thiele, *Ind. Eng. Chem.*, 1925, **17**, 605.

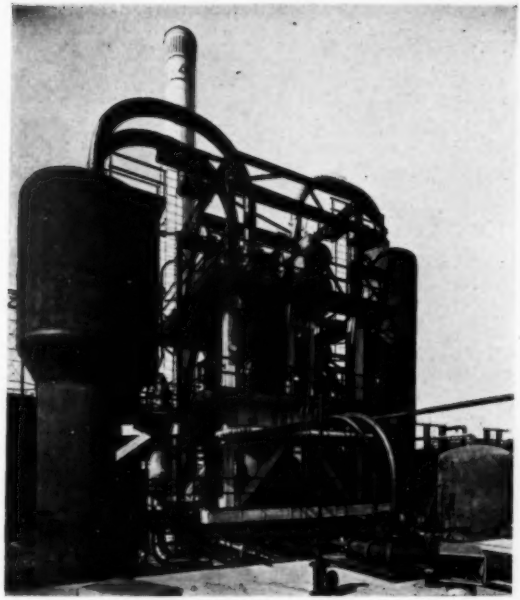

FIG. 1.

TWO-STAGE ATMOSPHERIC-VACUUM UNIT FOR RERUNNING PRESSURE DISTILLATE *(Courtesy, E. B. Badger & Sons Co.)*

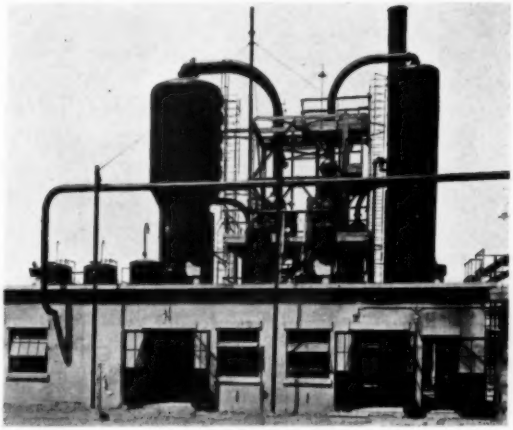

FIG. 1A.

TWO-STAGE ATMOSPHERIC-VACUUM UNIT FOR RERUNNING PRESSURE DISTILLATE TO PRODUCE CLOSELY FRACTIONATED CUTS.

(Courtesy, E. B. Badger & Sons Co.)

FIG. 2.

UNIT FOR STABILISING PRESSURE DISTILLATE.

(Courtesy, E. B. Badger & Sons Co.)

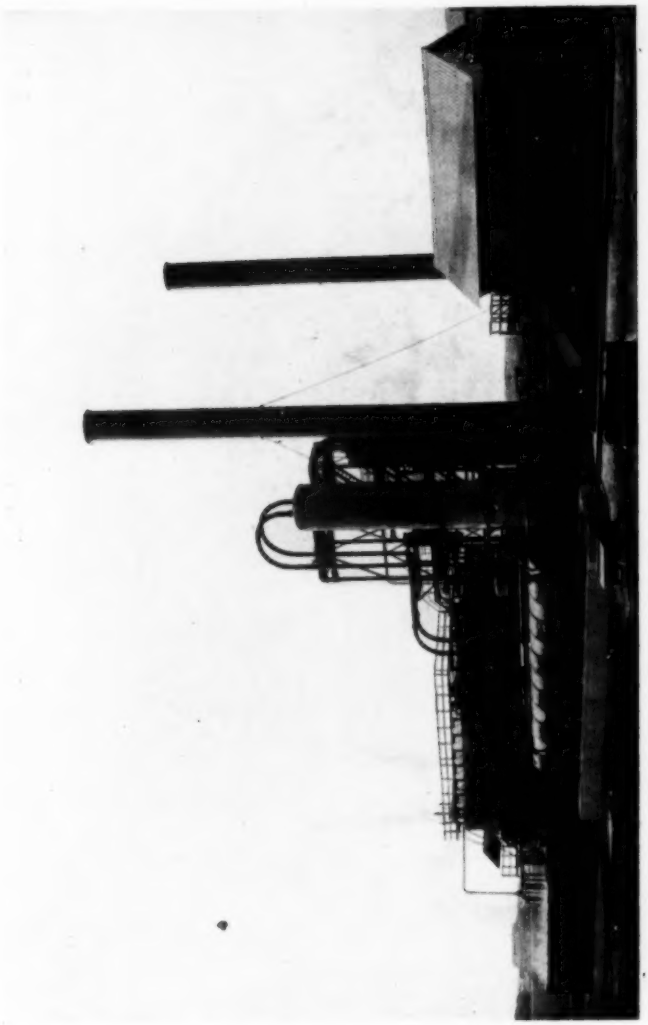

FIG. 3.
ATMOSPHERIC TWO-STAGE CRUDE OIL DISTILLATE UNIT. (*Courtesy, E. B. Badger & Sons Co.*)

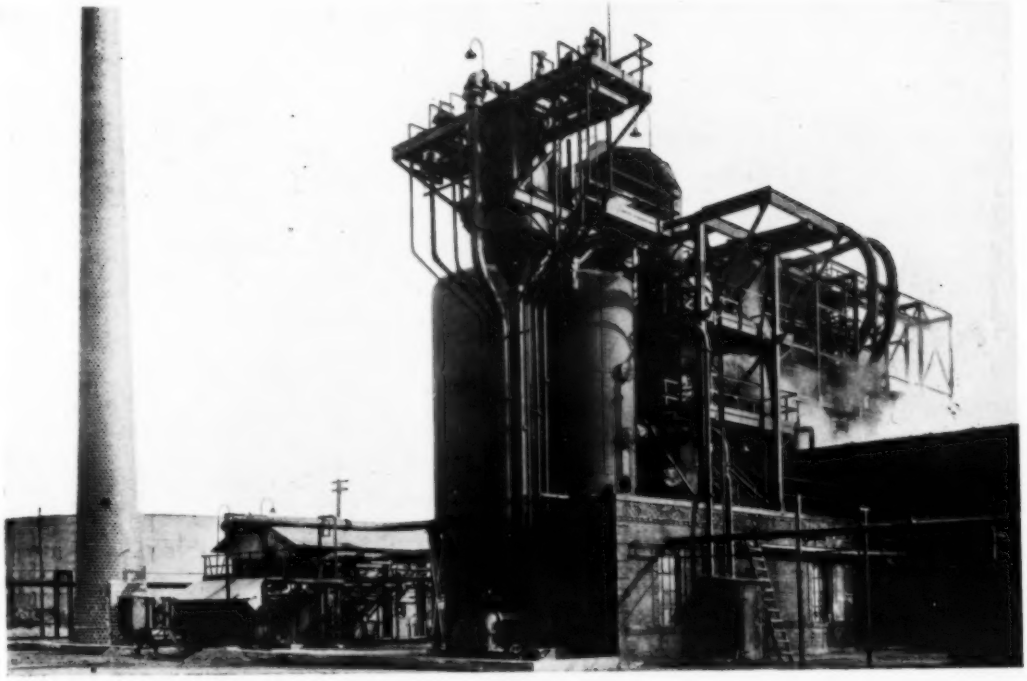

FIG. 5.

VACUUM SIDE OF TWO-STAGE UNIT DESIGNED TO TAKE ONLY ONE OVERHEAD CUT IN VACUUM STAGE. *(Courtesy, E. B. Badger & Sons Co.)*

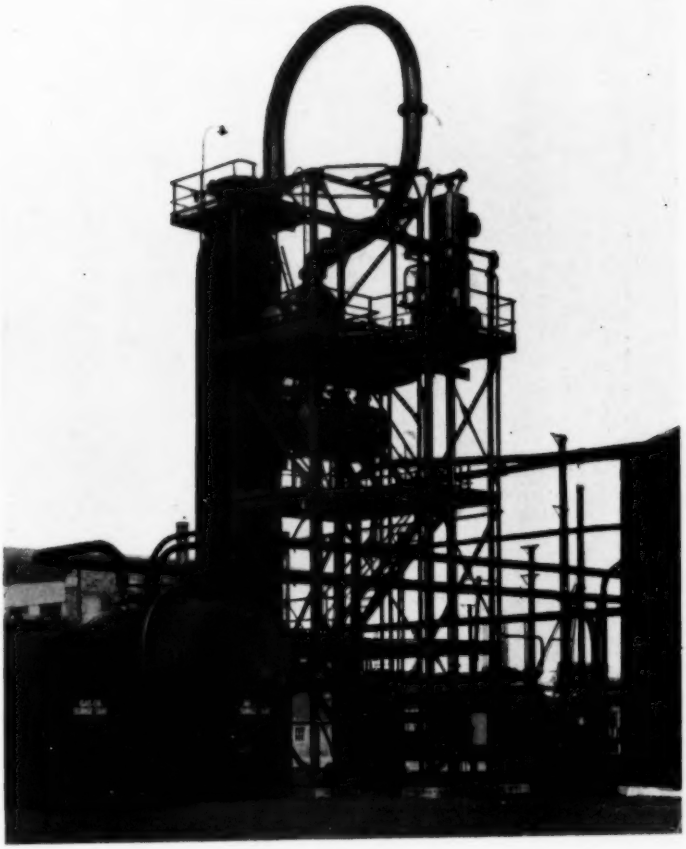

FIG. 6.

VACUUM JUG INSTALLATION.

(Courtesy, Foster Wheeler Corporation.

CUT IN VACUUM STAGE. *(Courtesy, E. B. Badger & Sons Co.)*

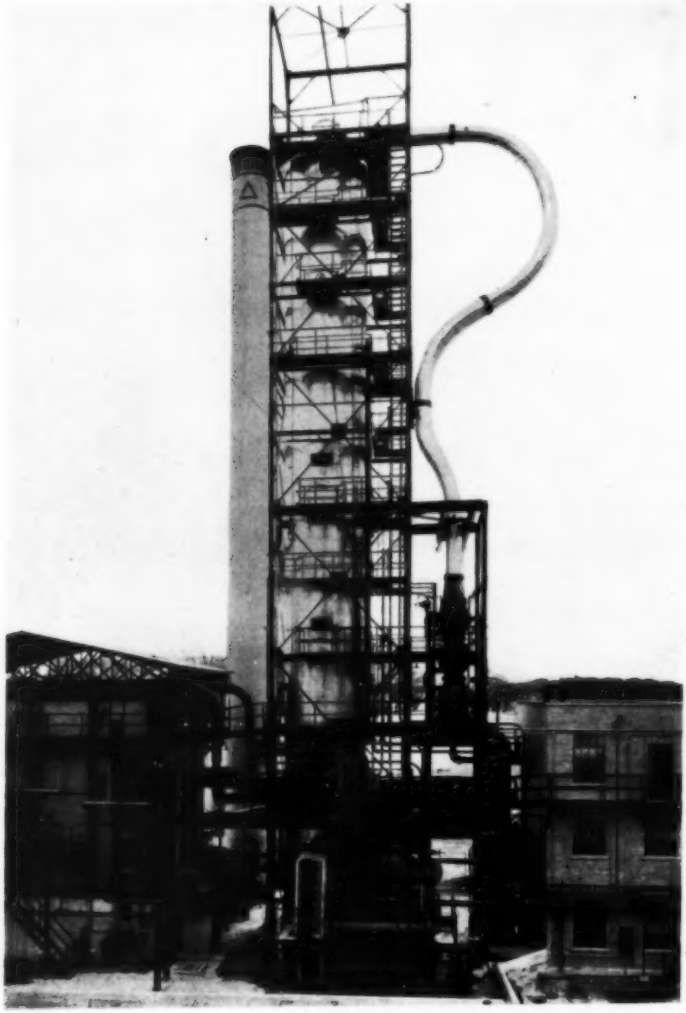

FIG. 8.

RERUN INSTALLATION FOR LUBRICATING OIL STOCKS.

(Courtesy, Foster Wheeler Corporation.)

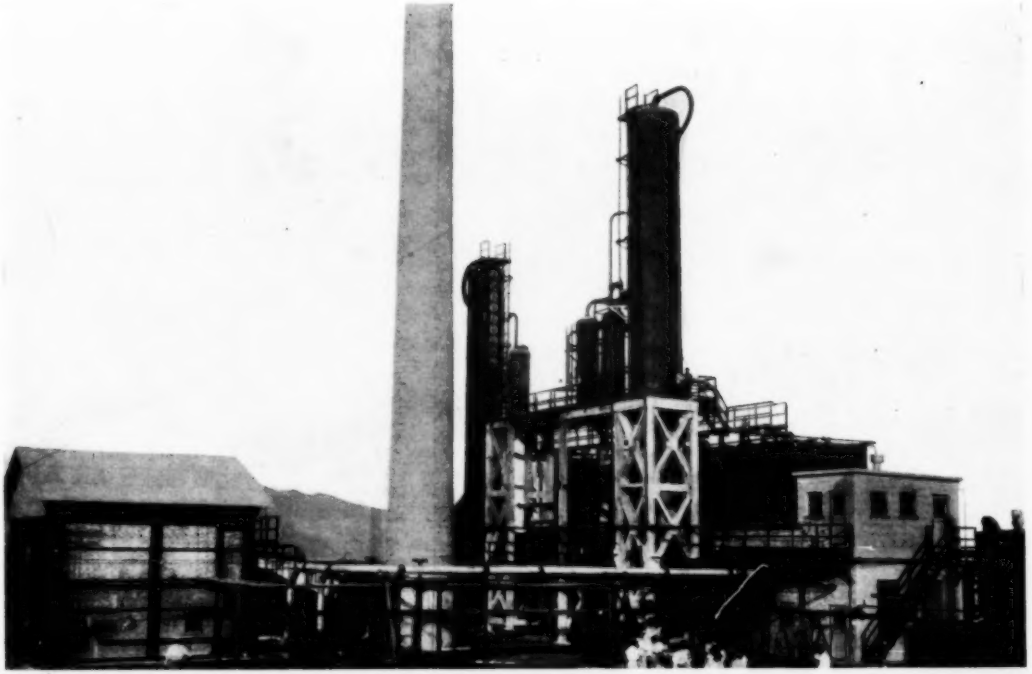

FIG. 9.

COMBINATION TOPPING AND VIS-BREAKER UNIT FOR VENEZUELA CRUDE OIL.

(Courtesy, E. B. Badger & Sons Co.)

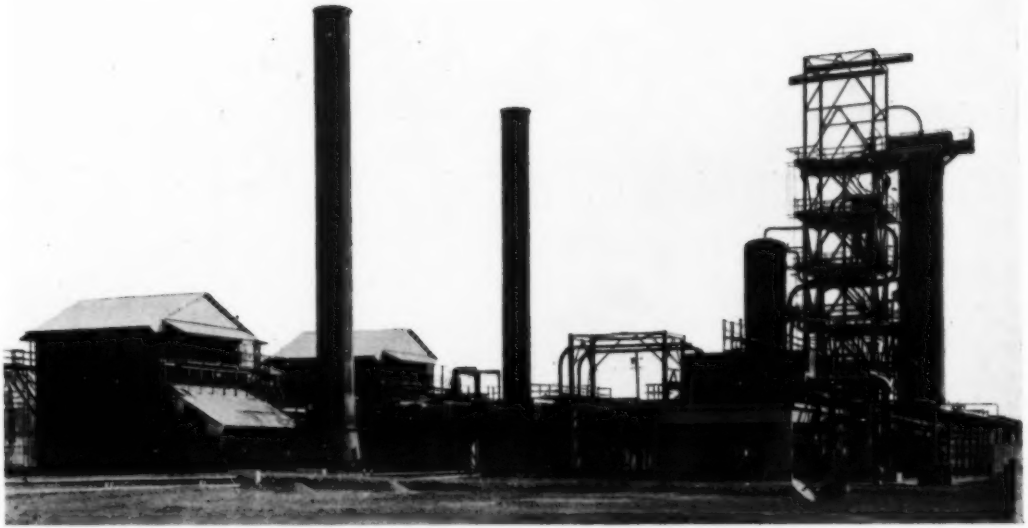

FIG. 10.

COMBINATION VIS-BREAKER AND CRACKING UNIT AT AVON, CALIFORNIA.
PLANT OF THE ASSOCIATED OIL COMPANY.

(Courtesy, E. B. Badger & Sons Co.)

(Courtesy, E. B. Badger & Sons Co.)

however, the use of automatic control has not shown marked progress during the past two years; in fact with better-built units and better functioning of these main controls, it has been found more practicable to control the remaining points, at least in the units operating at lower temperatures, by hand. Actually, there has probably been a decrease in the field of use of automatic instruments rather than an increase during this period.

Recording and measuring instruments such as thermometers, gauges, etc., are of course essential parts of a well-designed unit, and practically all the operation of a unit is usually concentrated at one point without the use of as much automatic control equipment as might have been considered desirable two years ago.

Pumps.—There has been no great change in the design of pumps which would affect the design of a distillation unit, but several units using all centrifugal pumps have been in operation long enough now to demonstrate their practicability. The use of centrifugal pumps has been found to give smoother operation and to give excellent results, with the minimum of control instruments.

Heat exchangers and tubulars.—There has been a marked tendency to reduce the number and size of heat exchangers and tubulars in petroleum distillation units. In one case a large installation was made without any tubular equipment at all. There are two reasons for this: first, the great difficulties experienced with tubulars both from mechanical defects and from corrosion, and second, the present low value of fuel. In many cases heat exchangers have given more trouble than they were worth. Many refineries which installed tubular condensers several years ago have definitely gone back to the cast iron coil condensers.

However, the manufacturers of tubulars have gone a long way towards solving the mechanical difficulties, so that it is to be expected that, when economically justified, heat exchangers will be installed to an increasing extent in the future.

Typical Installations.

Below are briefly described examples of the newer types of units which have been most generally installed during the past two years.

Two-stage pressure distillate rerun unit.—It has been found that when many treated pressure distillates are heated they give acid compounds even when they are completely neutralised before heating. The amount of acid compounds increases rapidly when the temperature reaches about 150° C., and in some cases the colour of the distillate begins to fall off at or even somewhat below

this temperature. With many treated distillates better results could be obtained when they were kept below 150° C. in rerunning. Some distillates, in fact, showed improvement when a temperature of 135° C. was not exceeded during the rerunning operation. Furthermore, prolonged heating, such as would be met with in shell still operation, was harmful, even at such low temperatures. Obviously, a single-flash distillation with steam would give any desired separation at the specified temperatures, but very large amounts of steam would be required. A single-stage vacuum unit could not be used since the light ends could not be condensed under vacuum. A two-stage unit, in which the light material was stripped out in a first flash and the final separation was made in a second vacuum stage, was developed.

One of the first of these two-stage units was put into operation in 1929, and since that time a large proportion of the pressure distillate rerun units built have been of this general type.

Many variations in the method of heating and vaporising the charge are in use, and the choice of method in any particular case will depend on the characteristics of the pressure distillate to be rerun and on the relative costs of steam, water and fuel. A discussion of various units with specific data on three types is given by Arthur G. McKee and Company.[13] In this discussion tables are given indicating fuel consumptions of less than 0·1 per cent. of the charge for this general type of unit, but there is probably some error in these figures.

An interesting table of comparative costs of the different types of units is also given in which it is stated that the cost of a two-stage direct heated atmospheric-vacuum unit will be 145 per cent. of a single-flash unit of the same capacity. This comparison is undoubtedly correct for the one capacity considered, but obviously the relation of costs will vary with the capacity, and for very large capacities the two-stage will cost little more than the single-stage unit.

Fig. 1 is a view of the fractionating equipment of a two-stage unit which will run 12,000 barrels per day of treated pressure distillate. The heat in this particular unit is furnished by a pipe-still. Steam is often used for heating in this type of unit, about 50 lb. of pressure steam per barrel charge being required for the heating above that used for pumps and ejector equipment. Exhaust steam from the pumps and ejectors will be used in the towers for distillation so the total steam consumption for a unit heated and run by steam will be 60 to 70 lb. per barrel charged.

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[13] *Nat. Petr. News*, 2.12.31, **23** (48), 33.

Operating data for the unit shown in Fig. 1 is as follows :—

Charge 12,000 barrels per day.	
Temperature of charge to atmospheric tower vaporiser.	129° C.
" " " from base of atmospheric tower	128° C.
" " " to vacuum tower vaporiser ..	130° C.
" " bottoms from vacuum tower	107° C.
" " vapours from atmospheric tower ..	112° C.
" " vapours from vacuum tower	70° C.
Pressure in vaporiser of vacuum tower	71 mm.
Steam to atmospheric tower (exhaust)	6·6 lb. per brl.
Steam to vacuum tower (exhaust)	5·0 lb. per brl.
Fuel consumption 0·41 gals. per brl. charged.	

A.S.T.M. distillations of charge and products :—

	Charge.	Atmospheric overhead.	Vacuum overhead.	Bottoms.
%	100	42	20	34
I.B.P.	42° C.	34° C.	140° C.	213° C.
10	85	56	151	222° C.
50	175	107	165	237° C.
90	248	165	185	—
E.P.	—	195	201	—

In this unit a sharp separation between the overheads from the two stages was not required. In some cases it may be desired to separate the two cuts rather sharply and to handle them separately. A unit to make such sharper cuts will use more steam and fuel and will have larger towers for a given capacity. Such a unit is shown in Fig. 1A, and the cuts from this unit are tabulated below :—

% I.B.P.	Charge. 53° C.	Atmospheric overhead. 33° C.	Vacuum overhead. 190° C.	Bottoms. 239° C.
10	92	67	194	247
50	179	129	202	262
90	302	175	214	312
E.P.	—	196	223	—

An older type single flash atmospheric unit in which the bottoms were recycled to give more complete recovery of light fractions is operating as follows :—

Temperature of charge to main tower	182° C.
Temperature of recycled bottoms from heater	210° C.
Steam in tower (exhaust)	27·5 lb. per brl.
Fuel in heater	0·48 gals per brl. charge.
Final boiling point of distillate	201° C.
Initial boiling point of bottoms (31·5 per cent. of charge)	220° C.

Comparing these figures with those given for the two-stage unit it is seen that the two-stage unit uses less fuel and steam and would therefore generally be installed on the basis of economic considerations alone where the capacity is large enough to bring the relative installation costs close together.

Stabilisation of pressure distillate.—Stabilising units are now being installed with many cracking units to reduce the losses in storage and treating of pressure distillate. In general these units are similar to the stabilisers that have become standard in the natural gasoline industry. A unit installed by the Simms Oil Company at Dallas was described by George Reid.[14] In this unit the combined pressure distillate from a cracking and a vis-breaker operation is fractionated under 50 lb. pressure and a temperature of 154° C. in the kettle at the base of the tower and 49° C. at the top of the tower. Under these conditions all of the propane and lighter and practically all of the butane is removed from the pressure distillate. The overhead gas or vapour then goes to an absorption plant, the recovered product from which is stabilised in a second unit operated at 215 lb. pressure and 143° C. in the kettle at the base of the tower. The stabilised material from this second stage will contain much butane and is used for blending.

A similar unit installed by the Continental Oil Company in Baltimore is described by W. T. Ziegenhain.[15] In this unit the stabilisation is also done in two stages, the first stage apparently operating at about 50 lb. pressure and 150° C. at the kettle and producing a gasoline with only 0·21 per cent. butane and no lighter products. The second stage operates with a temperature of 88° C. at the kettle and produces a stabilised product containing 60 per cent. butanes, which is used for blending.

(Fig. 2 shows a typical unit for stabilising pressure distillate.)

Two-stage topping unit.—Fig. 3 shows a unit designed to run Russian crude to about 50 per cent. bottoms by weight. Normally a single stage unit would be used for such an operation, but in this case the large capacity required, 25,000 barrels per day, and the sharp separation between gasoline and naphtha that was desired, made the two-stage operation preferable. The unit has actually operated at a rate of over 30,000 barrels per day. The following products (by Engler distillation) were obtained at capacities somewhat below this :—

	Gasoline.	Naphtha.	Kerosine.	Gas oil.
I.B.P.	—	162° C.	212° C.	284° C.
F.B.P.	150° C.	182° C.	291° C.	—

A flow diagram of the unit is shown in Fig. 4.

The gasoline was taken from a first tower into which the charge, preheated to about 150° C. by heat exchangers, is introduced. Steam may be introduced at the base of this tower or heat may be supplied by returning a portion of the bottoms after they are

[14] *Refiner*, July, 1930, **9** (7), 97.
[15] *Oil and Gas J.*, 11.9.30, **29** (17), 38.

heated in the pipe heater. Naphtha was taken from the top of the second tower and side cuts of kerosine and gas oil were taken from this tower as in a standard single flash unit.

Topping and vacuum unit.—In the two-stage topping and vacuum units which were constructed before 1930 several cuts were generally taken off in the vacuum section. This was particularly true in the case of units running paraffin base crudes, where a pressable wax distillate and an overhead cylinder stock was desired. One reason for this was that it had always been assumed that the wax distillate should be cut as sharply as possible, at the upper end, in order to get the greatest yield of a pressable stock.

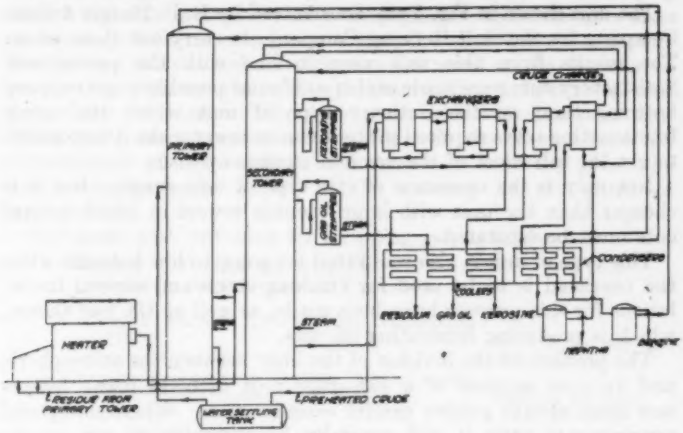

FIG. 4.

FLOW DIAGRAM OF ATMOSPHERIC TWO-STAGE CRUDE OIL DISTILLATION UNIT.

(Courtesy, E. B. Badger & Sons Co.)

This assumption was a natural outgrowth of the fact that, before fractionating equipment came into use, directs cuts of wax distillate could not be pressed, or at least very small cuts only could be pressed without rerunning. When the wax distillate was fractionated large cuts could be pressed. A wax distillate taken from the top of the vacuum stage tower will obviously be more sharply cut at the heavier end than if it were taken from the base of the atmospheric stage tower.

A second reason for taking the wax distillate off in the vacuum section was that no one believed the heavy cylinder stock could be vaporised by itself in a pipe still distillation. The lighter stock was thought necessary to carry the heavier stock off.

Not accepting either of these commonly held beliefs, Mr. H. G. Smith of the Gulf Refining Company proved, on a small scale, that extreme fractionation was not necessary to give entirely satisfactory heavy wax distillates and overhead cylinder stocks, and further that the heavy cylinder stocks alone could be vaporised in a properly designed vacuum pipe still unit. He proposed that the lighter wax distillates be taken off with fractionation in the atmospheric section, and that a single heavy cut be taken off in a relatively small and simple vacuum section. This vacuum section would not necessarily have any fractionating plates above the vaporiser, so that the maximum practicable effect of the vacuum could be obtained, where it was required, at the vaporiser.

The unit shown in Fig. 5 was constructed by E. B. Badger & Sons Company for the Gulf Refining Company, to carry out these ideas. The results from this unit were in line with the predictions. Satisfactory cuts were made and it was found possible to go to lower bottoms than on the ordinary type of unit where the many fractionating trays required in the vacuum tower make it impossible to get the full effect of the vacuum at the vaporiser.

Not only is the operation of this type of unit simpler, but it is cheaper than the unit with large vacuum towers in which several cuts must be separated.

This type of unit is also well fitted for going to low bottoms when the overhead is to be used for cracking stock and several installations for this purpose have been made, as well as the one shown, which is producing lubricating oil cuts.

The problem of the division of the duty between the atmospheric and vacuum sections of a two-stage unit involves many factors and must always receive careful consideration. Where no special requirements exist it will generally be advisable to run to the highest permissible temperature in the topping or first stage, taking off as few cuts as possible in the vacuum stage.

Vacuum jugs.—The so-called vacuum jug or flash tower is a development similar to that just described. On such a unit, shown in Fig. 6, a hot residual oil is charged directly to a flash tower or jug, where the light fractions are reflashed under a low absolute pressure, brought overhead, condensed, and accumulated in a vacuum run-down tank. On some occasions superheated steam is used in the tower to strip additional fractions of the charge which are not immediately vaporised upon entering the tower. In this instance, the jug is equipped with a steam coil at the base and bubble trays above, the heavy residuum being pumped away from the base of the tower in both cases.

Vacuum is maintained by steam jet air pumps which exhaust any non-condensable gases from the hot well tank. When process

steam is used in the jug a barometric condenser is placed between the hot well tank and the steam jets. With this arrangement the overhead from the jug consists of oil vapour, steam and non-condensible gas, the oil vapour being condensed into the vacuum run-down tank, the steam being condensed by direct contact with plant water in the barometrics, and the gases exhausted by the steam jet air pumps. Due to the absence of equipment which would produce any material pressure drop between the steam jets and the point of flash in the tower, a high vacuum is maintained at this point.

Considering this type of unit from an economic standpoint, it is apparent that the boiler-house steam used by the jets in creating the low absolute pressure, within the jug, is far more effective than an equal quantity would be in a simple atmospheric steam still. The process steam used for stripping purposes in the jug can be low-pressure exhaust steam if superheated to a temperature near that of the oil charge. The plant runs with only the part time attention of one operator. As in the unit described above the simplification of the vacuum flash tower or vaporiser gives the maximum practicable effect of the vacuum at the point of vaporisation.

Two units with provision for stripping ran as follows :—

1. Charging Mid-Continent residuum—15·5° A.P.I.—1405 brls. per day (residuum topped 84·5 per cent.).
   Products :
   Cylinder oil 20·0° A.P.I. 146 sec. Saybolt at 210° F. .. .. 320 brls. per day
   Flux bottoms 13·6° A.P.I. .. .. .. 985 „ „
2. Charging fuel oil from Dubbs (flashing operation) cracking process .. .. .. 936 brls. per day
   Products :
   Gas oil (for recracking) .. .. .. 281 „ „
   Asphalt—penetration 6, melt 153° F. .. 655 „ „

Rerun unit for dewaxed lubricating stocks.—Fractionating units are now employed for rerunning dewaxed lubricating stocks. One unit of particular interest has recently been put into operation for handling pressed paraffin distillate and cylinder stock solution, either separately or as a mixture. Fig. 7 illustrates the general oil flow of this unit while Fig. 8 shows the plant as erected.

Charging a mixture of pressed distillate and bright stock solution, the feed passes through heat exchangers to the tube still and is then flashed in a bubble column under atmospheric pressure where the overhead, three side cuts and bottoms are separated, using exhaust steam from the pumps, superheated in a section of the heater, for stripping the side and bottom cuts.

Charging a mixture of cylinder stock solution and pressed distillate is advantageous from a cost viewpoint. Frequently, a

batch of bright stock becomes contaminated in storage, in transit, in dewaxing or in the treating and contacting stage, with the result that flash points are low. By simultaneously refractionating this otherwise ruined batch with pressed distillate, the entire charge is

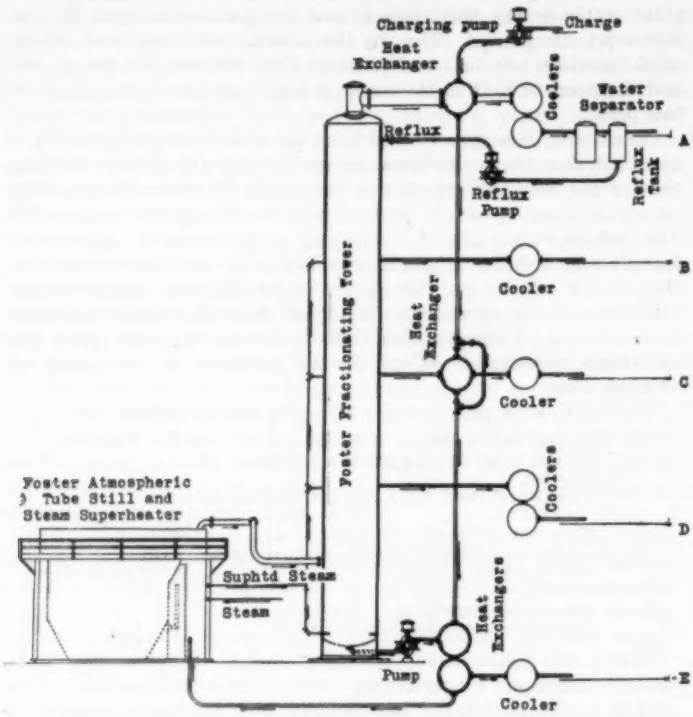

FIG. 7.

REBUN UNIT FOR LUBRICATING OIL STOCKS.

(Courtesy, Foster Wheeler Corporation.)

	Pressed Wax Distillate.	Cylinder Stock Solution.	Combined Pressed Wax Distillate and Cylinder Stock Solution.	Combined Pressed Wax Distillate and Cylinder Stock Solution.
A. ..	Gas Oil.	Naphtha.	Naphtha.	Naphtha.
B. ..	Lube 50 Vis. at 100° F.	Closed.	Gas Oil.	Closed.
C. ..	Lube 70 Vis. at 100° F.	Gas Oil.	Lube 50 Vis. at 100° F.	Gas Oil.
D. ..	Closed.	Closed.	Lube 185 Vis. at 100° F.	Lube 70 Vis. at 100° F.
E. ..	Lube 180 Vis. at 100° F.	Cylinder Stock.	Lube 160 Vis. at 210° F.	Lube 60 Vis. at 210° F.

handled as a synthetic crude and good separation obtained. Extra rerunnings are thus reduced.

The unit can make the change-over from one charging stock to another without excessive production of slop. A limited number of control points namely—

(1) The transfer temperature on the tube still.
(2) The temperature of the oil at the top of the column.
(3) Special weir reflux control valves at each side stream—

permit accurate control. Though the rate of charging may differ on each occasion, control temperatures and reflux valve settings will be identical with any throughput.

A summary of the three operations is given :—

1. Running pressed wax distillate—28·5° A.P.I.—cap. 8000 brls. per day.
   Products :
   Gas oil—34° A.P.I. .. .. 39% yield
   Lube A—30° A.P.I. 50 sec. Saybolt at 100° F. .. 10% „
   Lube B—28° A.P.I. 70 „ „ .. 20% „
   Lube C—26° A.P.I. 180 „ „ .. 31% „
2. Running bright stock solution—45° A.P.I., capacity 8000 brls. per day.
   Products :
   Naphtha 59° A.P.I. .. .. 70% yield
   Gas oil 30° A.P.I. .. .. 1·5% „
   Bottoms 26° A.P.I. 150 sec. Saybolt at 210° F. .. 28·5% „
3. Running mixture of bright stock solution and pressed dist. 40–45° A.P.I. capacity 7500 brls. per day.
   Products :
   Naphtha 59° A.P.I. .. .. 53·5% yield
   Gas oil 39° A.P.I. .. .. 3·5% „
   Lube A 28° A.P.I. 50–70 sec. Saybolt at 100° F... 10·0% „
   Lube B 26° A.P.I. 185 „ „ 100° F... 12·0% „
   Lube C 24° A.P.I. 160 „ „ 210° F... 21·0% „

3A. Products :
   Naphtha 59° A.P.I. .. .. 35% yield
   Gas oil 39° A.P.I. .. .. 19% „
   Lube A 28° A.P.I. 70 sec. Saybolt at 100° F. .. 6% „
   Lube C 26° A.P.I. 60 „ „ 210° F. .. 40% „

Combination topping, vis-breaker and cracking units.—The application of efficient fractionating equipment to cracking operations has resulted in the development of several types of combination units. Inasmuch as some of these combination units are notable rather more for the varied use of towers than for the application of new principles in cracking, it is not out of place to give a brief description of several types of such units here.

A combination topping and viscosity breaker unit is shown in Fig. 9. In this unit the Venezuela crude is charged through heat exchangers to a primary fractionating tower in which gasoline is removed overhead and kerosine and gas oil as side streams. The

topped crude is charged to a viscosity breaker, where 8 per cent. of gasoline is produced from the top of the fractionating tower and cracked kerosine and gas oil are taken off as side streams. The bottoms are Bunker C fuel oil.

Fig. 10 shows an installation in which 10,000 barrels per day of 0·95 specific gravity reduced California crude oil is charged through heat exchangers to a viscosity breaker. The heated charge from the viscosity breaker furnace discharges into the same towers as a 4000-barrel cracking unit in which is processed the gas oil obtained from the viscosity breaker, together with other lighter cracking stocks which may be introduced into the system. The combination of towers for the viscosity breaking and cracking stages results in a considerable saving not only of installation costs, but also in operating costs.

In units of low capacity the viscosity breaking operation is usually omitted, the reduced crude from the preheating and topping section passing direct to the fractionating system to be mixed with recycle stock and charged direct to the cracking system. In some cases the whole crude may be charged to the cracking system, in order to reform the natural gasoline fractions.

The demand for gasoline of high anti-detonating quality has led to an increasing number of vapour-phase cracking installations and the raising of processing temperatures on the liquid-phase operations. Combination topping and liquid-vapour-phase units in which the crude is topped by waste heat, the heavy gas oil is cracked under liquid-phase conditions and the lighter fractions including the heavy natural gasoline are charged to the vapour-phase side, have been made possible by the development of efficient pressure fractionating equipment.